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ABSTRACT

This research report contains a fairly concise overview of the role of constructivism in the teaching of mathematics and science in Finland. Included papers have been grouped into three parts. The first part, "General Considerations," consists of the seven articles on theoretical considerations, social constructivism, teachers' and pupils' beliefs, geometry teaching, development in physics teaching, constructivism in physics teaching and learning, and the idea of space in geography. The second part, "Research Projects," contains nine papers on the teaching of optics, student teachers' environmental awareness, changing pupils' beliefs, construction and assessment of conceptual and procedural knowledge, mathematics on the child's condition, real-time microcomputer-based laboratory tools, the comparison of teachers' conceptions, mental maps in geographical research and teaching, and teaching the force concept for engineering students. The third part, "Action Research at Schools," includes 12 short reports on the subjects of the teaching of chemistry, the teaching of physics, environmental project work, and the teaching of mathematics as well as two general reports on active working and motivational concepts. (Author/NB)

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Research Report

131

Maija Ahtee
Erkki Pehkonen (eds.)

Constructivist Viewpoints for School Teaching and Learning in Mathematics and Science

Department of Teacher Education
University of Helsinki

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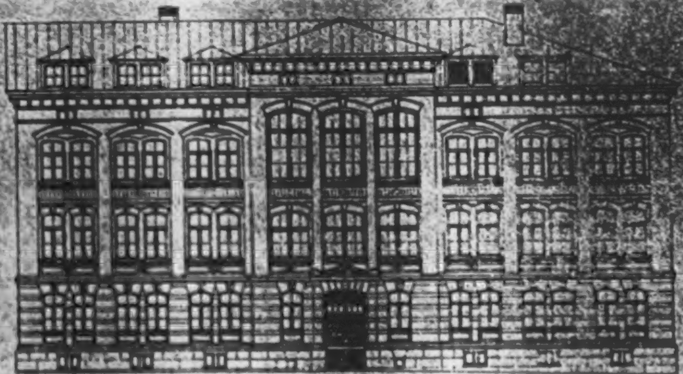

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Konstruktivistisia näkökulmia matematiikan ja luonnontieteiden opetukseen ja oppimiseen koulussa. 175 s.

Tiivistelmä

Raportti jakautuu kolmeen osaan. Ensimmäinen osa Teoreettisia tarkasteluja koostuu seitsemästä artikkelista, jotka käsittelevät konstruktivistisen oppimisnäkemyksen yleistä merkitystä ja kehityssuuntauksia. J. Leino, Teoreettisia tarkasteluja; O. Björkqvist, Sosiaalisesta konstruktivismista; E. Pehkonen Opettajien ja oppilaiden uskomuksista; T. Keranto Geometrian opettamisesta;M. Ahtee ja K. Seinelä Fysiikan opettamisesta, H. Rikkinen & L. Mikkola Spatiaalisesta ajattelusta maantieteen opetuksessa.

Tutkimusprojekteja osassa kuvaillaan yhdeksää käynnissä olevaa opetukseen liittyvää tutkimusta. Fysiikan opetukseen liittyvissä neljässä tutkimuksessa tarkastellaan valo-opin (M. Ahtee), lämpöopin (M. Erätuuli) ja voimakäsitteen (J. Viiri) opetusta sekä tietokoneen käyttöä laboratorio-opetuksessa (J. Lavonen). V. Eloranta käsittelee luokanopettajaksi opiskelevien ympäristötietoisuutta; H. Rikkinen & L. Mikkola spatiaalista ajattelua maantieteen opetuksessa. Matematiikan opetusta käsitellään artikkeleissa L. Haapasalo, konseptuaalisesta ja proseduraalisesta tiedosta; L. Häggblom, matematiikkaa lapsen ehdoilla; E. Pehkonen & L. Lepmann, opettajien uskomusten vertailua Virossa ja Suomessa.

Opettajien käytännössä toteuttamista opetuskokeiluista kahdessa L. Pehkonen, projektityöskentelystä ja A. Pietilä, motivaatioon liittyvistä käsityksistä tarkastellaan yleisiä opetukseen liittyviä aiheita; kolmessa J. Joki; J. Paasonen & M. Salmela; M. Rossi käsitellään matematiikan, kolmessa M. Aksela; T. Asunta; U. Komulainen & M. Ahtee kemian, kolmessa H. Levävaara; N. Lindroos & M. Ahtee; E. Leinonen & M. Rossi fysiikan ja yhdessä Kolari & M. Messo ympäristökysymysten opetusta yläasteella.

Avainsanat:
konstruktivismi, matematiikan opetus, luonnontieteiden opetus

UNIVERSITY OF HELSINKI
DEPARTMENT OF TEACHER EDUCATION

Research Report 131, 1994

Maija Ahtee, Erkki Pehkonen (eds.)

Constructivist Viewpoints for School Teaching
and Learning in Mathematics and Science. 175 pp.

Abstract

This book contains a fairly concise overview of the role of constructivism for teaching of mathematics and science in Finland today. The papers have been grouped in three parts. The first part, General Considerations consists of the seven articles: J. Leino on Theoretical considerations; O. Björkqvist on Social constructivism; E. Pehkonen on Teachers' and Pupils' Beliefs; T. Keranto on Geometry teaching; M. Ahtee on The development in teaching of physics; K. Seinelä on Constructivism in physics teaching/learning; H. Rikkinen & L. Mikkola on The idea of space in geography.

The second part, Research projects comprises the following nine papers: M. Ahtee on Teaching of optics; V. Eloranta on Student teachers' environmental awareness; M. Erätuuli on Changing pupils' beliefs; L. Haapasalo on Construction and assessment of conceptual and procedural knowledge; L. Häggblom on Mathematics on the Child's Condition; J. Lavonen on Real-time microcomputer-based laboratory tools; E. Pehkonen & L. Lepmann on Comparison of teachers' conceptions (Estonia and Finland); H. Rikkinen & L. Mikkola on Mental maps in geographical research and teaching; J. Viiri on Teaching the force concept for engineering students.

The third part, Action Research at Schools contains twelve short reports. M. Aksela; T. Asunta; U. Komulainen & M. Ahtee on teaching of chemistry; H. Levävaara; N. Lindroos & M. Ahtee; E. Leinonen & M. Rossi on teaching of physics; M. Kolari & M. Messo on environmental project work. J. Joki; J. Paasonen & M. Salmela; M. Rossi on teaching of mathematics. The reports of L. Pehkonen, Working actively and of A. Pietilä, on Motivational concepts deal with more general topics.

Key words: constructivism, mathematics/science teaching

Preface

During last years in Finland, there have been vivid discussions about improving school teaching. Especially among teachers and teacher educators of mathematics and sciences, the discussion about the role and implications of constructivism for teaching has been very active. In June 1992, there was a one-day specialist seminar on the theme Constructivism and Mathematics Teaching at the Department of Teacher Education in Helsinki, inspired by the book *Constructivist Views on the Teaching and Learning of Mathematics (eds. Davis & al. 1990, NCTM)*. In the seminar, the participants pondered what constructivism is and what it means for mathematics teaching in Finland. Based on this seminar, the book *Matematiikan opetus ja konstruktivismi – teoriaa ja käytäntöä [Mathematics teaching and constructivism – theory and practice] (eds. Paasonen & al. 1993)* was published in Finnish in the series of Reseach Report in the Department of Teacher Education at the University of Helsinki.

In this book we want to enlarge the view point from mathematics also to the teaching of science. The content of the book is three-fold: The first part presents the theoretical considerations which lie behind the reform of school teaching. In the second part, some of the on-going research projects which are carried out within the constructivist framework are introduced. The last section contains action research which active field teachers have carried out in their classes. As we aimed to a fairly concise overview on the present situation in Finland we restricted the pages of the articles so that in the first part the maximum number of pages is eight, in the second part six and in the third part only four. We regret if these limits make it hard for the reader to obtain a full understanding of the work which has been carried out in each case. We believe that the contributors are happy to inform you further, if necessary, and therefore, the addresses of the contributers are included at the end of the book.

Our warm thanks are due to all contributors. We want also to extend our thanks to the referees who helped us to ensure the level of each contribution. The use of the English language was checked by Ms Pearl Lönnfors (Language Centre at the University of Helsinki) whom we thank for the huge work done. Last, but not least, we express our gratitude to the Head of the Department of Teacher Education at the University of Helsinki, to Prof. Irina Koskinen who encouraged us to work further with our preliminary idea about having a book on the Finnish realization of constructivism and was ready to let the book be published in the Helsinki Report-series.

Helsinki, in March 1994

Maija Ahtee Dr., lecturer on physics and chemistry education	Erkki Pehkonen Dr., lecturer on mathematics education

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PART I: THEORETICAL CONSIDERATIONS

Theoretical considerations on constructivism

Jarkko Leino
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Constructivism emphasizes the learner's activity and previous experiences in knowledge forming. For a constructivist teacher, knowledge is created rather than transferred. Some teaching methods, such as project work and problem solving, fit very well constructivist teaching because they give the teacher better opportunities to follow the students working, to answer their questions and to make educated guesses as to how the students are thinking. Constructivist approach may mean an emerge of a new paradigm of mathematics as human-made, ever-changing, corrigible, imperfect, interconnected with the rest of knowledge, value-laden and culture-bound.

Introduction

Teaching and learning are complex phenomena to be studied. The models developed for this purpose have so far been rather rough. Though it has been a well-known fact that the learner's previous experiences have some importance in the teaching and learning process, these have usually had a minimal role because of their uniqueness. However, the ways the subjects (teachers and students) understand the situation in the teaching-learning process and construct their purposes may have a crucial role. The constructivist perspective holds as a chief assumption that the subjects being studied must at least be considered knowing beings, and that the knowledge they possess has important consequences for how their actions are interpreted (Magoon 1977).

Constructivism emphasizes the learner's activity in forming his/her own knowledge and previous experiences as the basis of activity. Knowledge is not formed as sense activity but through mental operations. We do not see or hear the external world as it is, but what we see and hear we choose and construct from external information on the basis of our previous knowledge and interpretation of the situation. This makes the stance towards knowledge problematic. Knowledge cannot be transformed as such, only information can be sent; the receiver has to construct his/her own knowledge. In order to have knowledge available for a comprehensive and independent use in our living world, it has to have many referentes and meanings. Knowledge which cannot be used for any purpose remains useless.

Traditional teaching and constructivist teaching

Traditionally, mathematics is taught as pure, to be applied in different fields acccording to the need. During the development process, mathematics has been separated as a science from contacts with reality, and it has purposefully been striving to attain a position of logically- consistent and complete systems, independent of all possible interpretations in reality. This has been elevated to the status of the truth criterion in the field. Accordingly, teaching does not consider it necessary or even possible to take students' previous mathematical experiences of the topic into account, because these are individual, take too much time from proper teaching and form a collection of confusing, situation-bound stories. In this tradition, knowledge is simple, clean, referent-free and, hence, meaningless.

As a consequence, students view the nature of mathematics in a special way (Pehkonen 1993): the right answer in each task and following the sequence of the syllabus in the textbook are important; the tasks of the textbook are real mathematics, not the teacher's extra tasks; and it is the teacher's duty to check and confirm the correctness of the answers. Though all mathematical concepts, structures and ideas have been invented as tools to organize the phenomena of the physical, social and mental world, it is difficult for the student to connect school mathematics with his/her everyday life. Freudenthal (1983) wrote a whole book to show the mathematics teacher the places where the learner might step into the mathematical knowledge of each elementary concept and into the learning process of mankind. Freudenthal's approach can be used in making teaching constructivist.

For a constructivist teacher, knowledge is created rather than transferred. The teacher tries to understand how students construct and use their knowledge and understandings. He/she can model student thinking by using multiple data sources, solving problems, working in groups, participating in classroom discussions, and using flexible ways of assessment. (See e.g. Confrey 1992, Cochran & al. 1993.)

Constructivist teaching is much more difficult than traditional. The teacher has to integrate subject matter knowledge, pedagogical knowledge, student characteristics and the environmental context of learning. Teacher education programs must focus on this kind of pedagogical content knowledge, if effective and congruent with research. This may mean that teacher education has to occur in contexts similar to the teacher's work in a classroom environment because only in this way can the pedagogical content knowledge be viable to teacher students.

From traditional to constructivist teaching

So far, we have very little experience and few models of constructivist teaching. As I have experienced it, the easiest step to the constructivist direction can be taken in teachers' in-service education in which school development programs can be organized in this way (e.g. Leino 1991). In different disciplines the change process may be different. If it is true that "all mathematical pedagogy, even if scarcely coherent, rests on a philosophy of mathematics"(Thom 1972), then constructivism demands the change in the philosophy of mathematics as well.

Lakatos (1977) distinguished two general views of the nature of mathematics: (1) the Euclidean view regarded knowledge as universal, certain, absolute, value-free and abstract whereas (2) the Quasi-empirical view regarded it as socially constructed, relative in truth, and as answers to some real problems. According to the latter view, we call knowledge true if it is useful and consistent within our current understanding and experiences. The Euclidean view is dominant and foundational to our present teaching practice.

Some studies seem to show that the teacher's view of the nature of mathematics has at least a moderate connection with the way of teaching mathematics (e.g. Lerman 1990), which means, for example, that the teacher who views mathematics as absolute also demands the teaching to be the same. However, this is hardly the whole truth. The nature of mathematics can be seen as a continuum, the extreme ends of which have only been taken into account by Lakatos. And besides the truth criterion, there may be other aspects, such as aesthetic, motivational, and process-bound aspects. Modern technology in particular forms a powerful factor stressing a new nature of mathematical knowledge. Teachers may also emphasize different aspects depending on the levels they are teaching, e.g.

motivational aspects and solving everyday problems in elementary and junior secondary schools. The absolute nature and proofs are stressed only in the advanced courses of senior secondary school. (Leino 1975.)

If we look at the studies of the most motivating methods in elementary and junior secondary school, we have to admit that students' quasi-empirical work, such as project studying in teams and problem solving, are the most suitable. These methods give students opportunities to use their previous everyday experiences. Problem solving seems to be the way which charms and challenges, at least the most able students. On the other hand, those students who have difficulties form another extreme group which often compels the teacher to penetrate into their thinking in order to be able to help them. Thus both extremes of students seem to benefit from constructivist teaching.

Some teaching methods, such as project work and problem solving, fit constructivist teaching very well because they give the teacher good opportunities to follow the students working, to answer their questions and to make educated guesses as to how the students are thinking.

Often teachers use the project method for motivational purposes only, but do not want to conceptualize its proper goal. Teaching, of course, can also be a technical affair. However, constructivist teaching involves the teacher's whole personality and compels him of her to conceptualize in advance why something is really worth doing, what the students should aim at and how the results are to be evaluated. (See Ormell 1992).

Constructivist teaching gets its nourishment from the research of learning, and the humanistic approach. To my mind, it is time to substitute the view of absolute knowledge in mathematics and see it as human constructs of the problems faced. A new paradigm of mathematics as human-made, ever-changing, corrigible, imperfect, inter-connected with the rest of knowledge, value-laden and culture-bound is already emerging (Ernest 1992).

One of the major problems in constructivist teaching is combining students' working and subjective theories with the scientific knowledge of the field, i.e. it has to answer the question of how students can find the generally accepted mathematical concepts and become familiar with their use. There is a dialectical relationship between individual knowledge, arrived at by reflecting on one's own activity, and knowledge that is socially mediated or jointly agreed on. In the latter type, mathematical concepts include, knowledge which is created through a social process, in the dialectical interplay of many minds. In the classroom, students and teachers are working on a certain mathematical situation, and acceptance of the constraints of using a certain concept reflects the fact that understandings have been negotiated and institutionalized. This working will probably increase students' strategic skills and the use of spontaneous, everyday and subjective concepts. Scientific concepts and ideas to be elaborated in the learning situation often come from and are controlled by the teacher. This is the stage where scientific knowledge comes into the view. Prawat (1993) has described in detail this process and used Vygotsky's concept of "zone of proximal development"(Vygotsky 1978, 86).

Vygotsky regarded concepts as psychological tools to promote learning and dealing with complex situations. The focus of teaching is on practical activities, but the goals are in the growth of understanding. To solve an acute problem the learner needs tools; and scientific concepts can serve as such, introduced at the right moment, i.e. when needed. Understanding grows in two directions: on the one hand, by reflecting on one's own experiences in terms of a scientific concept, the learner becomes conscious of its meaning and forms interpretations of it in the domain of his/her personal experiences, and, on the other, scientific concepts also help him/her to move from context-dependency toward the higher characteristics of concepts. Scientific concepts are used for restructuring and raising spontaneous concepts and ways of knowing within the zone of proximal development. It means the outgrowth of a collaborative effort between adult and student and a self-conscious type of learning (Prawat 1993, 11).

Concluding remarks

The tradition of teaching as stressing academic contents in some disciplines and practical work in others cannot be defended any more in the light of current educational research, though it still dominates in politicians' speeches and educational practice. The same concerns the distinction between theory and practice in any discipline: it is not possible to justify the old system of theory-first-application-later. Good learning means trying to highlight both content and practice or theory and application simultaneously.

The static nature of the curriculum as the list of contents with preferable teaching methods does not work any more. This does not mean that scientific concepts and ideas have no position in the curriculum. Constructivist teaching does not only mean working, hands-on activities and solving problems followed by process assessment. What we have to do in a school is to get teachers to view the curriculum as a network of ideas, larger topics and projects in a sequence that promotes students' understanding and educational development. The teachers' task is to plan what a piece in the network of curriculum means within an individual school, and how to work it out along with the students as a kind of coach or guide, not forgetting to introduce the important scientific concepts when necessary for development and widening perspectives. (Cf. Prawat 1993.) School-based development and curriculum can offer an excellent framework for "a new school, a new nature of knowledge and a new conception of learning".

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Social constructivism and assessment

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The function of assessment is analyzed within a constructivist - and particularly a social constructivist - framework for mathematics education. The special role of the teacher is emphasized.

Constructivism and assessment

With the present popularity of constructivism as a general framework for teaching and learning mathematics, the problem of assessment has become increasingly evident. How is it possible to assess the quality of the knowledge constructed by another person in an objective way? Assessment would seem to require some kind of *comparison* of the knowledge of a student with a standard, but the comparison itself requires *communication* which is expected to be incomplete. The best one can hope for is a general picture which is put together from pieces of information.

The standard itself constitutes a problem. Is it enough to consider mathematics as resting on objective truths that can be used as knowledge standards? The *discoveries* of mankind are based on this kind of assumption. In the case of mathematics - that there exists true mathematics waiting to be discovered. Criteria for the assessment of the knowledge of the students can then be derived from what is known about true mathematics.

This puts constraints on the process through which knowledge is constructed. In fact, it means that students construct two kinds of knowledge, *real* knowledge which agrees with real mathematics, and other knowledge of a personal type. Real knowledge is then actually discovered rather than constructed, and the process in the classroom is one of *guided discovery*. There would seem to be no need to rename that process "constructivism".

Radical constructivists reject the possibility of obtaining real knowledge about the world, including mathematics (von Glasersfeld 1987). The construction of knowledge is not guided by truth criteria. During the process of construction, students experience various cognitive conflicts - *viable* knowledge is knowledge that comes out of these conflicts and gives, at least temporarily, an understanding of the world of experience. The sense of a *direction* for the development of knowledge is spurious. The process is rather similar to the one introduced by Darwin - the knowledge that is most adaptable to a variety of situations is the knowledge that survives.

The concept of viable knowledge may be attractive to other than radical constructivists. It may be used to describe a sequence of *improved models* for the structure of the real world, a developmental idea which is acceptable to "weak" or "trivial" constructivism. In such a case it is reasonable to derive assessment criteria from what is known about the real world.

For any constructivist, there remains the problem of formulating criteria to be used in formal assessment, *acceptable to society*.

Social constructivism

Despite the differences in views between various kinds of constructivists, they will agree that the construction of knowledge takes place with social interaction as a major influence upon the individual. Students are affected by their families, teachers, and other students, and they learn from their total experience. To emphasize this, the term *social constructivism* has been suggested independently by several authors. Ernest (1991) traces the concept to the view of the development of science in society represented by Lakatos (1978) and Popper (1979). He describes (1990) his own theory of mathematics in society as inspired by Bloor (1976) and Restivo (1988). Björkqvist's view of science education (1990) was similarly inspired by Solomon (1987). Others that must be mentioned are Weinberg & Gavelek (1987) and Lerman (1989).

An important element of social constructivism is the consideration of the knowledge that is common to a specific group of people. The mathematical knowledge that dominates in a specific culture may be called *collective knowledge*, and our special interest is in the relationship between the collective knowledge and the knowledge of the individual.

If your view is that of a radical constructivist, this collective knowledge is the best that you can get as a standard to be used in assessment.

Ernest (1991), following Popper, calls it "objective knowledge", using a term that might also be associated with properties of the real world. Calling it "collective knowledge" avoids confusion. In either case it refers to Popper's World Three.

If you are not a radical constructivist, you may choose to view collective knowledge as a set of models corresponding to or converging towards properties of the real world.

Collective knowledge is characterized by its ties to a specific culture or group of people at a specific moment in time. Mathematics is viewed as a social construction. New mathematics, created by individuals, is included in collective knowledge through a process of acceptance using criteria that are socially defined. The same kind of process may lead to rejection of previously accepted pieces of collective knowledge. It is important to note that falsification is only part of this process. The history of mathematics gives numerous examples where cultural conditions in general, or personal connections, have been decisive for the construction of new collective knowledge. What we call mathematics is a collection of concepts and methods that have proved viable in society.

Collective knowledge may be viable to a certain group of people while at the same time it is not viable to another. An example is found in the use of the abacus. When different cultures collide, old knowledge may be assimilated, modified or rejected. Ethnomathematics (Lave 1988) has clearly shown that this process need not lead to the homogenization of collective knowledge, since the process often is influenced by competing criteria of viability.

The other aspect of the interrelationship between collective knowledge and the knowledge of an individual is the way in which the individual includes pieces of collective knowledge in his own construction of knowledge. Social constructivism emphasizes the unique capacity of man to receive abstract information through oral or written *communication*. It is a foundation for cultural traditions and for the survival of scientific knowledge from one generation to another. The system of organized education itself expresses the importance of learning through social interaction.

When a student in school constructs his mathematics, he will use his teacher as a reference. His assessment of the quality of his own ideas will be a process of a predominantly social kind. Acceptance by the teacher will be an indication that he may continue to reason in a similar way in the future. There is rather less self-assessment using mathematical arguments. There may, however, remain a considerable amount of individual knowledge which differs from collective knowledge and nevertheless is viable for the individual.

A description of the mechanisms that make an individual change his conceptions requires a constructivistic theory of learn-ing. Self-assessment would seem to be an important component in such a theory. If personal criteria exist for the quality of knowledge, they may be inaccessible by others, and of course they can be expected to be changing as a result of social interaction.

The concept of viability at the individual level is thus subjective. There are related concepts that appear reasonable to associate with the existence of viable conceptions, e.g., the subjective feeling of *understanding* (Björkqvist 1990). On the other hand, there is considerable documentation (Meyerson & McGinty 1978) of unusual behavioural patterns that are stable and give evidence of individually viable mathematics, while at the same time there is no evidence of understanding, other than in an instrumental sense.

The latter can be seen as an exemplification of pragmatism on the individual level. The social context very often is such as to present mathematics as a *useful* subject, a tool. And of course, there is reason to see it that way. Viewed from the point of future success for the individual in the struggle for survival, an investment in mathematical knowledge opens up many possibilities, and mathematics usually is just a means towards other ends. Self-assessment and formal assessment of mathematical knowledge must acknowledge that.

However, as social constructivism also emphasizes, mathematics is *dynamic* and responds to changes in society. Its usefulness on the social and cultural level presupposes a continuous influx of new ideas, and those must come from individuals. A restriction in formal assessment, focussing only on mathematics and that has previously proved useful, will quench that flow.

Man has the unique capability of investing in future knowledge which will help him as a species in a variety of ways. Such mathematical knowledge may not be recognizable at the time of its birth, but the methods of assessment should include mechanisms that encourage creativity. The teacher is in a critical position in this difficult task.

A necessary property for a conception to be socially viable is that it can be communicated. On an elementary level, this requires sufficient agreement regarding concepts and methods employed by two or more people at a particular moment. In mathematics, the definitions of concepts have been made systematically exact and the methods have been standardized, i.e., one tries to maximize communicability by use of conventional concepts and methods. Those are to be counted as part of our scientific culture. Traditional assessment is directed towards them to a considerable extent.

In a constructivistic perspective, too, there is reason to assess the relatively static aspects of the mathematics of the students. The aim is not to assess reproductive ability, but to promote communicability and interaction with collective mathematical knowledge.

Assessment influenced by constructivism also includes dynamic aspects, assessing the process through which the student creates knowledge that is new to him and assessing the quality of the constructs with respect to viability in foreseeable and unforeseeable situations. It entails increased attention to the student's present view of mathematics. It also requires assessment of his active endeavours to change his conceptual world quantitatively and qualitatively, independently and in collaboration with other individuals in society. It furthermore involves assessment of the degree to which the personal knowledge is context-dependent.

Assessment from a constructivist perspective does not require old methods of assessment to be discarded, but rather that they be complemented with new methods. It is imperative that such new methods are rendered acceptable in society, since the formal way of assessment normally influences the way in which education is organized.

Social constructivism implies a strong emphasis on the role of the teacher in the process by which the students construct their knowledge. The students test their conceptions primarily on the teacher and gradually, with the support of the teacher, independently by self-assessment. The teacher analyzes their way of thinking and attempts to predict the effects when it is confronted with other ways of thinking that may predominate in society. Part of the teacher role is promoting the development of metacognition, making the student aware of his own thinking and that it may differ from that of others.

The teacher is the representative selected by society to maintain collective knowledge - the culture of mathematics - available to the students.

Considering the changing nature of collective knowledge and the conditions of society, this is not a definite, but a provisional position of authority - a matter of confidence in a professional. The picture includes the expectation that the teacher, better than anybody else, is capable of placing the conceptual world of a student in a developmental perspective. The teacher also is the one to make decisions in cases where different criteria for the viability of knowledge are to be balanced against each other, for instance individual creativity and precision in conventional terminology.

Social constructivism assumes that the teacher has visions of the social development of mathematics and that those visions are actually put into use in the planning of educational activities and in the assessment of the outcomes of them.

It is remarkable that social constructivism, while firmly based on the view that each individual constructs his own knowledge, should imply such an important role for the teacher in that process. As a theory, it appears to restore to the mathematics teachers much of the status that they formerly had. However, the expectations with respect to teacher knowledge and skills are quite different.

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Teachers' and pupils' beliefs in focus – a consequence of constructivism

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The concept of belief is discussed very briefly, and its close connections with teaching and learning are pointed out. Some aspects of changing beliefs are also dealt with. At the end, there are some references for further literature.

When considering constructivism (e.g. Davis & al. 1990) as a basis for the understanding of teaching and learning mathematics, it follows that teachers' and pupils' mathematical beliefs have a key role when trying to understand their mathematical behaviour (e.g. Noddings 1990). When mathematics educators are describing school instruction using the constructivist framework, teachers' and pupils' beliefs are necessarily involved (see e.g. Leder 1992).

What are beliefs?

Although beliefs are popular as a topic of study, the theoretical concept of "belief" has not yet been dealt with thoroughly. The main difficulty has been the inability to distinguish beliefs from knowledge, and the question is still unclarified (e.g. Thompson 1992).

There are different contents for the concepts "belief" and "belief system" used in studies in the field of mathematics education. As a consequence of the vague definition of the concept, many researchers have formulated their own definition for "belief". For example, Schoenfeld states that, in order to give a first rough impression, "belief systems are one's mathematical world view" (Schoenfeld 1985). He later modifies his definition, interpreting beliefs as an individual's understandings and feelings that shape the way that the individual conceptualizes and engages in mathematical behavior. Hart (1989) uses the word belief to represent a certain type of assessment pertaining to a group of conceptions. Lester &

al. (1989) explain that "beliefs constitute the individual's subjective knowledge about self, mathematics, problem solving, and the topics dealt with in problem statements". Whereas Thompson (1992) understands beliefs as a subclass of conceptions. Yet another different explanation is given by Bassarear (1989) who sees attitudes and beliefs on the opposite poles of a bipolar dimension.

Here, we understand beliefs as one's stable subjective knowledge of a certain object to which tenable grounds may not always be found in objective considerations. Beliefs are adopted and abstracted from the individual's personal experiences, for the reasons which are defined by the individual self – usually unconsciously. The adoption of a belief may be based on some generally known facts (and beliefs) and on logical conclusions made from them. But each time, the individual makes his own choice of the facts (and beliefs) to be used as reasons and his own evaluation of the acceptability of the belief in question. Thus, a belief, in addition to knowledge, also always contains an affective dimension. This dimension influences the role and meaning of each belief in the individual's belief structure.

Beliefs are in close connection with attitudes. A very common definition of attitude is a tridimensional one, where beliefs form one component. For example, in the dictionary of Statt (1990, 11), one may find the following definition for attitude: "A stable, long-lasting, learned predisposition to respond to certain things in a certain way. The concept has a cognitive (belief) aspect, an affective (feeling) aspect, and a conative (action) aspect." Saari (1983) had a similar idea, when he tried to structure the central concepts of the affective domain through grouping them into three categories: feelings, belief systems, and optional behavior. Thus, he understood, for example, that attitude has a component-structure, and that beliefs form a component of attitudes.

In his study, Saari (1983) suggests that belief systems are seen to be developed from simple perceptual beliefs or authority beliefs – via new beliefs, expectations, conceptions, opinions and convictions – to a general conception of life. In accordance to this, we may explain that conceptions are conscious beliefs, and thus we understand conceptions as a subset of beliefs. Conceptions are higher order beliefs which are based on such reasoning processes for which the premises are conscious. Therefore, there seems to be a basis for conceptions, at least they are justified and accepted by the person himself.

The role of beliefs in teaching and learning

The beliefs the teacher has about mathematics and its teaching and learning strongly influence his classroom management, as well as the effectivity of his teaching (Goldin 1990). The National Council of Teachers of Mathematics (NCTM 1989) asserts that teachers play an important part in the formation of pupils' beliefs about mathematics. Furthermore, Lerman (1983) pointed out that the teachers' philosophy (or the view) of mathematics has influences on and shapes their teaching practice.

The central meaning of pupils' mathematical beliefs has been noticed. For example, Baroody & Ginsburg (1990) state that beliefs can have a powerful impact on how children learn and use mathematics. Borasi (1990) stresses that pupils who have rigid and negative beliefs regarding mathematics and its learning easily become passive learners who emphasize remembering more than understanding in learning. Spangler (1992) points out that beliefs and learning seem to be in a cyclic relationship: Pupils' learning experiences will contribute to their beliefs, and on the other hand, their beliefs will influence how they approach new mathematical experiences.

In her dissertation, Martha Frank (1985) introduced a scheme for some factors affecting pupils' problem-solving behavior. Her scheme has been reorganized and adapted to the case of a teacher's actions during mathematics lessons (Fig. 1). A similar scheme may be worked out in the case of a pupil's beliefs, only the box with "administrative orders" may be left out.

Beliefs have a central role as a background factor for a teacher's thinking and acting. A teacher's mathematical beliefs act as a filter which deals with almost all his thoughts and actions concerning mathematics. A teacher's prior experiences in mathematics teaching and learning, which strongly guide his teaching behavior (e.g. through models), fully act on the level of beliefs – usually unconsciously. When he is using his mathematical and pedagogical knowledge, beliefs are strongly involved.

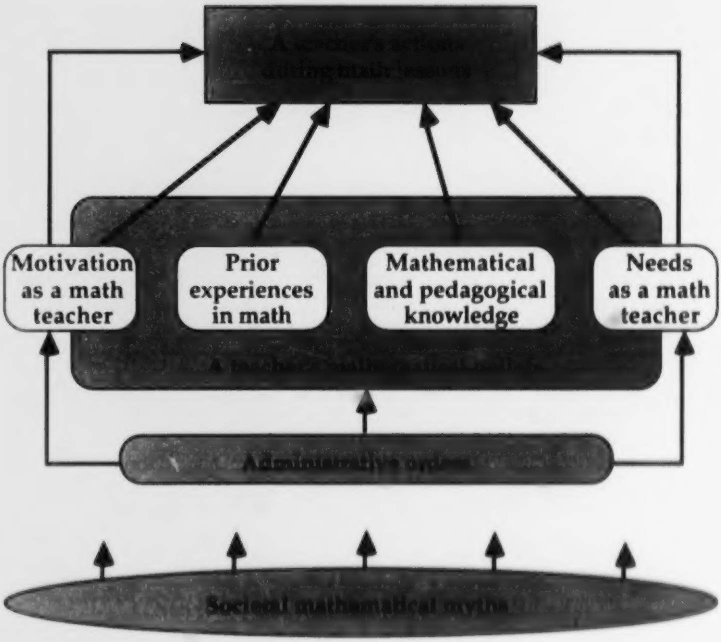
A teacher's actions during math lessons
Motivation as a math teacher
Prior experiences in math
Mathematical and pedagogical knowledge
Needs as a math teacher
A teacher's mathematical beliefs
Administrative orders
Societal mathematical myths

Fig. 1. Factors affecting a teacher's mathematical behavior.

On the other hand, the teacher's motivation and needs as a mathematics teacher are not only connected with his mathematical beliefs. For example, a teacher's need to receive a salary for the work done may affect his actions in classroom, and is not necessarily connected with his mathematical beliefs. In addition, there are different factors in the societal environment affecting the teaching situation, which will set limits for a teacher's actions: Besides different administrative orders (requirements), such as the mathematics syllabus, the number of lessons, and the lesson-break-cycle, which determine the situation, there are societal mathematical expectations and myths, e.g. mathematics is calculations (for more myths see e.g. Frank 1990).

The net of factors affecting via beliefs a teacher's mathematical behavior, described in Fig. 1, will reveal only a part of the truth. In fact, the situation is more complicated: The teacher functions in a complex net of influences, Underhill (1990) talks about a web of beliefs – there are colleagues, the school principal, the school administration, math supervisors, teacher educators, and parents who all have their own beliefs about the nature of mathematics and the nature of learning and teaching mathematics.

Changing mathematical beliefs

One of the most up-to-date fields of emphasis in the research of mathematics education has been the exploration of teachers' beliefs and of possibilities to change them (Thompson 1992). Usually in developing teaching, teachers' deep beliefs about mathematics teaching have not been taken into account (e.g. Kaplan 1991), and these deep beliefs factually guide teachers' actions. However, many methods of developing teaching try to change the teachers immediately. It has been thought that if teachers could see, understand and internalize the need for change and if methods to realize the change were provided, the curriculum and teaching materials would not form any obstacles. But only lecturing about the need for change and demonstrating the methods to realize it is not enough, since we are then still on the surface level of beliefs.

Teaching in school aims to change pupils' beliefs – also in mathematics. Green (1971) defined teaching as the developing of pupils' belief systems into becoming more unified. In addition to subject knowledge, pupils have many beliefs about the nature of mathematics and teaching/learning mathematics. Many of these pupils' beliefs are not "healthy" in that they form an obstable for effective learning. For example, "Formal mathematics has little or nothing to do with real thinking or problem solving", "Mathematics problems are always solved in less than 10 minutes, if they are solved at all", "Only geniuses are capable of discovering or creating mathematics" (Schoenfeld 1985, 43). In order to help pupils' to develop a more proper view of mathematics, they should be aware of their own beliefs about mathematics. Spangler (1992) suggests that one medium for bringing pupils' beliefs to a concious level is open-ended questions. Some examples of the questions Spangler has used are as follows: "If you and a friend got different answers to the same problem, what would you do?", "How do you know when you have correctly solved a mathematical problem?"

Endnote

In this paper, it is only possible to point out some central questions in the research on mathematical beliefs. Therefore, we will here give some further references in the literature: For general discussion on the concept and properties of beliefs see e.g. Nespor (1987), Pajares (1992). For research on teachers' mathematical beliefs see e.g. Underhill (1988b), Thompson (1992), Pehkonen (1993), and on pupils' mathematical beliefs see e.g. Schoenfeld (1985), Underhill (1988a), Pehkonen (1992). The international comparison of teachers' and pupils' mathematical beliefs is an almost unexplored field, where the studies by Pehkonen & Lepmann (1993, 1994) and Pehkonen (1994) seem to be among the first explorations.

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Geometry teaching and creative mathematical activity: Theoretical scrutiny

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This article analyzes the present state of geometry teaching, outlining ways to better promote mathematical thinking and proving skills. The analysis is based on Lakatos' ideas of the development of mathematics and of the nature of creative mathematical activity. The theoretical discussion is illustrated by examples.

Some critical notes

As we know, geometry and its teaching have a tradition of thousands of years which even today has an influence even on mathematics curricula. The purpose of many mathematics textbooks is still to teach basic geometrical concepts and theorems according to the Euclidean deductive tradition. Even though axioms are not presented as axioms, theorems are not presented as theorems, and there is no formal proving, the teaching proceeds from a point to a straight line to a plane. In addition to this, it is regrettable that the structure of the textbooks is formalistic: first "theory", then "practice" (see for instance the mathematics textbook *Taso 9*, pp. 56-67, "Space geometry")..

The chapter ("Space geometry") referred to above ends with a passage entitled "Platonic solids" (pp. 64–65). The reader's interest is awakened. Are the pupils finally allowed to discover or invent on their own something connected with these solid figures? Are they, for instance, asked to find out how many different regular polyhedrons exist? Why are there five of them and no more? And are the pupils allowed to examine if a relation exists between the number of vertices, edges and faces in these polyhedrons which is similar to that between the vertices and sides in planar polygons?

This hope is in vain! The same philosophy of "infallible mathematics", which offers ready-made solution models and leads to authoritarian and teacher-centered teaching strate-gies, is also obvious in the pages mentioned above, as well as in the competing series of books. It is not a miracle that the picture of mathematics (structure and activity) held by pupils and mathematics students has proved to be very one-sided and narrow. Mathematics is mostly thought of as calculation and as a pre-worked, infallible discipline of science, in which even the discovery of new things proceeds deductively from basic propositions to theorems (de Villiers 1986, Frank 1988, Thompson 1992).

So, something should be done. It is obvious that the teaching-learning processes should involve more discussion and they should make better use of the different experiences and solution models that the students have (cf. Cobb et al 1992, "inquiry mathematics", Freudenthal 1983, "didactic solution", Keranto 1990, "contextual strategy"). In addition, it is certainly not a bad thing if the pupils get to see how mathematical knowledge has increased and changed over the centuries. For this purpose, I will outline the nature of creative mathematical activity and its realizations in school geometry.

On creative mathematical activity

Creative mathematical activity can be compared to construction, because everything may appear – and actually is – very confused and unfinished to start with, both on a building site and in mathematics. The building itself begins to take shape little by little in the middle of all the additional structures and construction waste. In mathematics, these additional structures can be subsidiary figures or drawings which identify the structure of a problem. However, these are no longer referred to and are no longer visible in the finished building or proof. Finally, all the places are cleaned up – of course, a building may also remain unfinished – and the result is a product which does not necessarily as such reveal much of the creative and sometimes "smudgy" process that actually led to its completion.

The process in question is particularly evident in the elaboration of geometrical concepts, proofs and theorems. For instance from the historical development process of the Descartes-Euler problem (see Appendix 1), it may be observed that the mathematical activity which creates something new essentially involves "cultivated guesswork". In other words, the deductive structures and proofs in mathematics, which appear incontestable and are "tidy", have often been arrived at through trial and error. Everything has not really been as smooth and certain as one might imagine when examining scientific articles and textbooks written in the deductivist style. *Stoikheia* (in Latin, *"Elementa"*) by Euclid, for instance, which was thought of as the real description of the surrounding world and the ideal of strict and logical mathematics until the 19th century, contains a number of unnecessary definitions, undefined yet useful concepts and invalid proofs. Correspondingly, the strict logical systematization and accurate representation of the analysis was preceded by a lengthy stage of intuitive and illogical growth and development (for further details, see e.g. Kitcher 1984, 229–271, Kline 1980, 127–152, Lakatos 1976, 127–141).

Geometry teaching in the constructivistic way: a fictitious example

On the basis of what has been said so far, there are good grounds for efforts to change the teaching of geometry towards creative mathematical activity. This offers natural opportunities for personal invention and for debate to develop the proving skills. The pupils get a chance to organize and conceptualize the subject matter on their own. In the same context, one can see the real position and tasks of the definitions in the process of conceptualization. It is obser-ved that definitions are mostly needed as an aid in the deductive organization of the subject matter and in the clarification of the discussion that is going on.

As an example, let us look at a fictitious teaching session, in which the pupils are asked to solve, in pairs, the geometrical problem described below (the examination makes use of Balacheff's research, 1991, see also Lakatos' ideas 1976):

> Describe a way to determine the number of diagonals in a
> polygon for which the number of vertices is known.

Teacher: "The answer to this problem should be formulated in such a way that any of your friends, the same age as you, could make use of the solution"

Groups 1 to n start working in pairs, while the teacher follows them and takes notes. Let us assume that the notes reveal that groups 1 to 4 interpreted the term "polygon" as meaning a regular polygon and the term "diagonal" as meaning the diameter of a regular polygon. Let the resulting proposition be $f(n) = n/2$. Let as further assume that groups 5 and 6 discovered the general solution through trial and error, for example, in the recursive form

$$f(n) = f(n-1) + (n-2),$$

in which n equals 3 or an integer greater than 3.

These autonomous attempts to provide a solution are then followed by a general discussion in the classroom, which begins so that the teacher asks groups 1 to 4 to present their proposed solutions on the blackboard: $f(n) = n/2$.

Pupil A (group 5): "The proposition is not universal!"

Teacher: "Mathematical disputation essentially involves argumentation. Can you present the counter-example?"

Pupil A: "9 diagonals can be drawn in a polygon with six sides, for instance, and not 3 as suggested (a "global counter-example" to all the proposed solutions on the blackboard).

Pupil B (group 1): "How can you say that? You can draw two diagonals inside a square, for instance, and three diagonals inside this polygon with six sides, as you can see in this figure" (draws an equilateral hexagon with three diagonals on the blackboard).

Pupils C, D and E (groups 1 and 4): "That´s how it is!" (almost in unison)

Pupil F (group 6): "Another six diagonals can be drawn in that figure. By the way, the sides of a polygon need not be the same length!" (comes to complete the drawing)

Teacher: "F is right. Groups 1 to 4 have confined themselves to examining regular polygons and interpreted all the diagonals as diameters" (the pupils in groups 1 and 4 nod their consent).

Teacher: "What do groups 1 to 4 now think about their propositions?"

Pupil G (group 3): "F is right. We will try to amend our proposition."

Pupil H (group 2:) "We too. We reached our conclusions far too hastily."

We could continue this fictitious teaching session, in which we finally arrive, alternating with discussion and work in pairs, at the discovery of a universally applicable solution model and at a clearer understanding of the concepts of a polygon and its diagonals. It is essential that this fictitious teaching-learning process should offer opportunities for the kind of autonomous discovery and discussion that manifests the basic nature of creative mathematical activity: if you have a proposition, always be prepared both to prove and disprove it. Furthermore, it is essential that a discussion is initiated on attitudes towards different types of counter-examples and on what ultimately guarantees the validity of a proposition in mathematics.

Summary and conclusions

It is obvious that the implementation – either full or partial – of processes such as those outlined in the previous chapters requires a new kind of attitude among teachers and pupils towards the solution of mathematical problems and towards creative mathematical activity. It calls for persistent intellectual exertion which takes plenty of time and effort, and one has to be ready to make propositions and disprove them at the same time. It involves critical analysis and synthesis both of one's own and others' propositions and proofs. It also involves constant organization and conceptualization of the area of research using new theoretical concepts – such as convexity, and even continuity etc. – which evolve in the process of proving and replace the naive and intuitive concepts.

The learning can result in the development of the mathematical way of thinking and of the proving skills. More general models of thinking and action, connected with constructive discussion and debate, may also be set as targets. It is certainly not bad for the sound self-confidence of pupils either if they observe that even great mathematicians have been limited in their deductions and have made mistakes, and that they may – thanks to proper guidance – also achieve results similar to those reached by the mathematicians of earlier generations.

I think it is important that serious efforts are made in the teaching of geometry, in particular, to prove propositions resulting from "cultured guesswork". This is the very way for pupils to internalize the fact that the truth of mathematical theorems is ultimately based on the logical tightness and universality of the proving process and not, as many pupils seem to think, on pragmatic validations and induction (de Villiers 1991). In addition to this, proving based on deduction has an important explanatory function for the pupils. Why, for instance, do the segments connecting the centers in an arbitrary quadrangle always confine an area that is similar to a parallelogram in form? When problems like this are solved, the chances are also good for a local organization of the subject matter, and this can be one phase in the need to develop the axiomatic system itself.

Finally, I feel that it would not be a bad thing at all if geometry lessons ended more often in this remark from Lakatos' book: "But I had no problems at the beginning! And now I have nothing but problems!" (remark by Beta, pupil from the fictitious class, p. 105).

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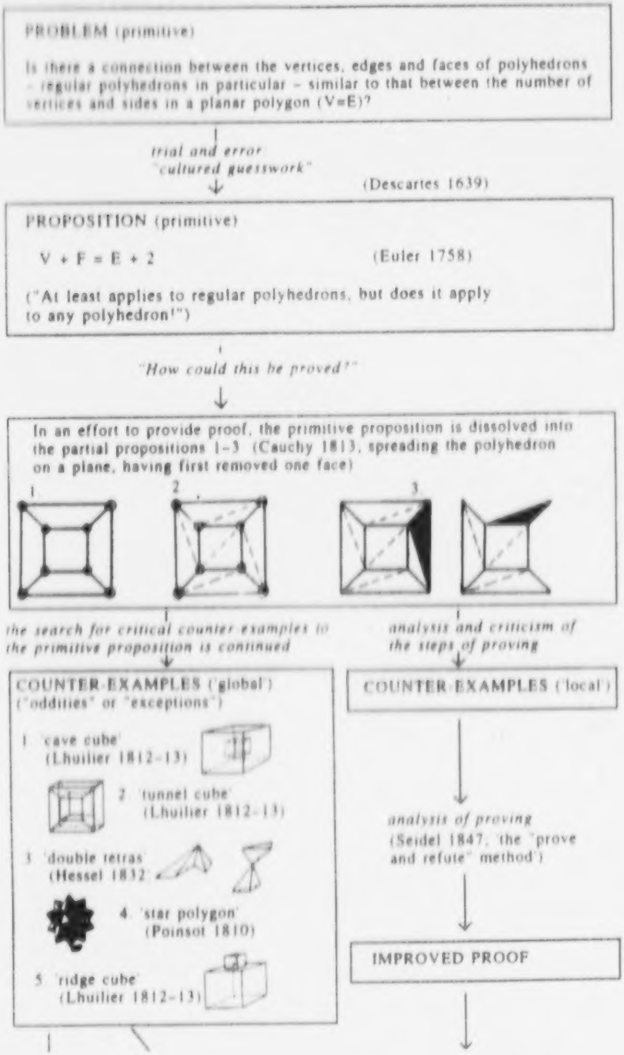
Appendix 1 Diagram of the historical development process of the Descartes-Euler problem on the basis of Lakatos' analysis (1976, 6–126).



PROBLEM (primitive)

Is there a connection between the vertices, edges and faces of polyhedrons – regular polyhedrons in particular – similar to that between the number of vertices and sides in a planar polygon (V=E)?

trial and error
"cultured guesswork"

(Descartes 1639)

PROPOSITION (primitive)

$V + F = E + 2$ (Euler 1758)

("At least applies to regular polyhedrons, but does it apply to any polyhedron!")

"How could this be proved?"

In an effort to provide proof, the primitive proposition is dissolved into the partial propositions 1–3 (Cauchy 1813, spreading the polyhedron on a plane, having first removed one face)

the search for critical counter examples to the primitive proposition is continued

COUNTER-EXAMPLES ('global')
("oddities" or "exceptions")

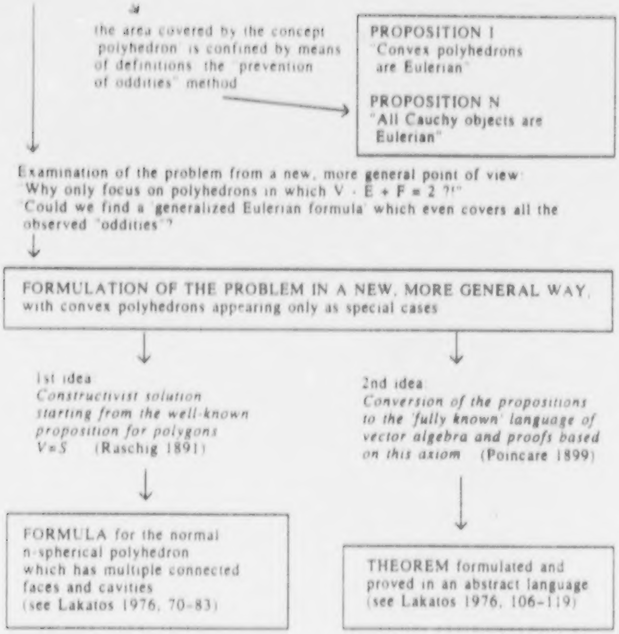
1. 'cave cube' (Lhuilier 1812–13)
2. 'tunnel cube' (Lhuilier 1812–13)
3. 'double tetras' (Hessel 1832)
4. 'star polygon' (Poinsot 1810)
5. 'ridge cube' (Lhuilier 1812–13)

analysis and criticism of the steps of proving

COUNTER-EXAMPLES ('local')

analysis of proving
(Seidel 1847, 'the "prove and refute" method')

IMPROVED PROOF


the area covered by the concept 'polyhedron' is confined by means of definitions: the "prevention of oddities" method
PROPOSITION I
"Convex polyhedrons are Eulerian"
PROPOSITION N
"All Cauchy objects are Eulerian"
Examination of the problem from a new, more general point of view:
"Why only focus on polyhedrons in which V - E + F = 2 ?!"
"Could we find a 'generalized Eulerian formula' which even covers all the observed "oddities"?
FORMULATION OF THE PROBLEM IN A NEW, MORE GENERAL WAY, with convex polyhedrons appearing only as special cases
1st idea:
Constructivist solution starting from the well-known proposition for polygons V=S (Raschig 1891)
2nd idea:
Conversion of the propositions to the 'fully known' language of vector algebra and proofs based on this axiom (Poincare 1899)
FORMULA for the normal n-spherical polyhedron which has multiple connected faces and cavities (see Lakatos 1976, 70-83)
THEOREM formulated and proved in an abstract language (see Lakatos 1976, 106-119)

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The development in teaching of physics

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The way of teaching physics is seen to have changed first from being traditionally product stressing to empiristic process-centred. The present constructivist view also includes the active participation of the learner. This development corresponds to the changes first from a theoretical approach to an experimental one and then also taking into account the constructions of the learner.

Introduction

In the 1980's the studies of pupils' pre- and misconceptions became dominant among the research into physics teaching with the constructivist view as the leading theoretical framework (Duit 1993). Accordingly the pupils have their own understanding about the world surrounding them, they develop their own interpretation for the meanings of the physical concepts and behaviour of the phenomena based on their own observations and experiences. The children's ideas are therefore difficult to change.

According to Confrey (1990), the present research on pupils' conceptions in science is based on two approaches, namely on Piaget's genetic epistemology and ontological considerations of how knowledge has changed with the development of science, as described by Kuhn and Popper.

In this article three questions are considered: 1) How has the teaching of physics developed constructivistically? 2) How does the constructivist point of view fit with the nature of physics? 3) What kind of guidance does the constructivist perspective give for teaching physics?

The development of teaching and learning in physics

One of the most striking features in the ***traditional way*** of teaching physics is the importance given to the product or theory either in the form of formulae or of definitions, like *$F = ma$, energy is ability to do work*. This theoretical approach (Kurki-Suonio, K. & R. 1987) has resulted in pupils learning by heart what is to them meaningless "empty" sentences, like *sound is a longitudinal wave motion*. This does not explain to them, for example, the fact that the sound changes when the length or thickness of the strings on a guitar is changed. On the other hand, the teaching method which follows from considering facts as most important delivers information. From the learner´s point of view, this leads inevitably to reception learning. If the learner is interested and tries to understand through his own thinking and former knowledge, this is a good way of teaching, especially if the teacher collects and organizes the necessary information. Ausubel (1968), however, makes a clear distinction between two kinds of reception learning, namely rote and meaningful learning. According to him, rote learning does not lead to understanding, and therefore, meaningful learning is often left to the learner to work out without necessary help.

The traditional way of teaching physics can thus be accused of paying too much attention to the physical laws and their predictions. This is seen, for example, as an overemphasis placed on the role of mathematics or calculation in solving physics problems. Snow (1961) critisized this kind of product-thinking stating that the scientific knowledge has only meaning when one understands how knowledge has been formed, what it is based on, or shortly what the nature of science is. Gradually more attention was given to the process, the scientific method. Also the learners were taken into account by starting to practice the process skills already on the primary level (Harlen 1985).

In the traditional way of teaching a lot of information is learnt but in many cases only superficially. In ***the empirist way*** of teaching and learning the stress is on "*learning by doing*". The view is that physics starts with simple independent observations which form the base for inductive generalizations. The assumption is that physics is best learnt observing carefully and identifying regularities or patterns which lead eventually to conceptual explanations. Especially at the primary level, this kind of instrumentalist view of the scientific method has led to simplified applications in teaching. For example, the teacher may show how water stays in a glass turned upside down when covered only by a piece of paper. This observation is supposed to lead to the understanding of the concept of air pressure and also the changes of weather as its consequence. Hodson (1988) has strongly critisized this way of applying the discovery–learning method: "Discovery methods can legitimately investigate the relations between concepts but they cannot, with certainty, lead to the formation of new concepts and new conceptual structures".

An assumption in the empirist view is that the senses are reliable and they give the same information to everybody. Andersson (1989) gives an example of what a teacher and a pupil see when they look at the same grain of salt through a microscope. The teacher draws a cube, as she knows that the crystal structure of NaCl is cubic. The pupil draws a rounded oblong, perhaps trying to get the picture to resemble a grain of corn. Both observations are guided by the observers' knowledge structure.

In the empirist view, learning is still seen as the absorption of knowledge, as "I did not catch it". According to ***the constructivist view,*** learning requires the active participation of the learner (see Osborne and Wittrock 1983; Driver and Erickson 1983; Gilbert and Watts 1983). Learning depends on what the learner already knows, her previous conceptions and motivation. The learner has to construct her own meaning of the words and sentences she reads and events she observes. For example, the meaning of fair test became clear to a group of seventh graders who could not explain their experimental results until they noticed the variation in the initial temperatures of the different samples (Lindroos and Ahtee 1994).

According to the constructivist view, a word or a sentence means different things to different people, depending on the person's knowledge and history. This is well illustrated by Solomon (1992) in her book about energy. The constructivist perspective has been applied in teaching so that the learners' earlier experiences, including knowledge and existing ideas, have been taken as the starting points for teaching. This approach has close connections with Ausubel's meaningful learning theory. As a consequence, an active research on students' and also on teachers' existing conceptions in physics and other fields of science has been established over the last twenty years (Duit 1993). As learning is seen as conceptual change, various models of learning have been introduced (Posner et al. 1982; Osborne and Wittrock 1983)

Components of teaching in physics, the three worlds

Traditional teaching in physics concentrates on the main concepts, laws and theories of physics. The theoretical approach (Kurki-Suonio, K. and R. 1987) stresses the results which are often seen as truths. Its starting point is *the world of scientific theory* which has developed throughout the centuries to its present form. Even though it has been formed by human thinking in its ideal form, it has risen above human influence. Originally theoretical concepts, like globe or atoms, have become objects which can be observed.

The empiristic view of teaching implies that physics starts from simple observations in *the real world* of phenomena, i.e. in nature. These observations provide an experimental base for concept formation, like average velocity should be seen as interpretation of the ratio $\Delta s/\Delta t$, the change in the position of the body divided by the time interval (Arons 1992, Ahtee et al. 1991). Experimental laws and theories can be drawn as inductive generalizations through a perception process. A necessary condition for a good theory is that it predicts something new, besides explaining the facts on which it is based. However, in explaining the observations and making the hypotheses, theoretical concepts as well as laws and theories are needed. The interplay with the world of theory is a long and continuous process. The concepts of physics form a pyramid with the later concepts at the top. Their formation is based on the earlier ones, like electric current is determined through the measurement of the force acting on two parallel wires. On the other hand, the meaning of the earlier concepts also enlarges on the progress of physics. For example, force is considered as an interaction between bodies or systems whereas in early mechanics it was understood as push or pull.

The constructivist view brings still another world into the teaching of physics, *the everyday world* or the pupil's world. It is impossible to jump straight from the observations and experiences met in the real world to the world of theory as it is seen today. Everybody has to perceive, ponder and even create their own explanation for various events. In the beginning these explanations were based on single events, incidental details and external properties and were mixed with outside information which could be understood in various ways. Only slowly will the everyday world come closer to the world of scientific theories.

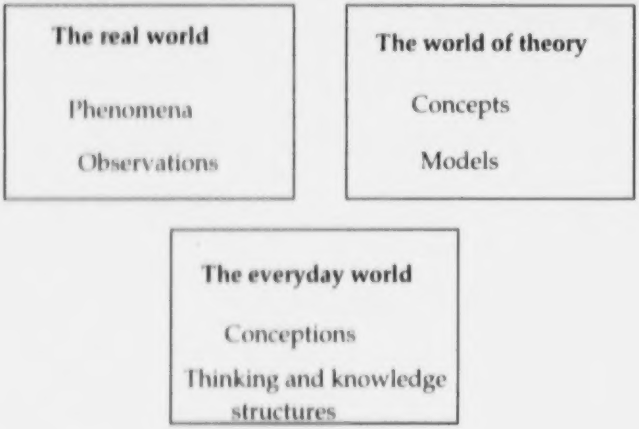

Fig. 1. The three worlds of teaching physics.

This division to the three worlds in Fig. 1 can be compared with Popper´s three worlds of reality (Popper and Eccles 1977). Popper´s World 1 is the physical world of sense perceptions and contains physical bodies and processes, like celestial bodies, gases or sound. World 2 is the world of mental states in which an individual´s constructions consists of his subjective experiences. World 3 is the world of the products of human thinking focussed on the objects in Worlds 1 and 2. These are, for example, stories, tools, works of art, social institutions, scientific problems, and scientific theories (true or false). Popper´s World 1 corresponds to the real world in Fig. 1, and the world of scientific theory is only part of World 3, containing only the well verified and, by the scientific community, accepted theories. It changes and develops more gradually whereas the everyday world is in turmoil because it contains socially acquired knowledge which has different meanings in different contexts. The abstract world of theory is created by human thinking, but it is universal, independent of any person. The everyday world contains constructs of the human mind. Every individual, including the scientists, has to reach the world of theory through the everyday world, which is the world in which he collects his experiences and makes his observations as well as does his thinking.

Suggestions for teaching

Looking from the traditional point of view, physics is a body of knowledge to be taught. In the behavioristic setting, learning is seen as a process of making associations, which often means memorizing facts and applying formulae with the teacher showing first and then asking the pupils to practice. The teacher's task is also to organize the content of the material to be learnt and make it suitable, meaningful and attractive to the pupils. A good model of teaching is, for example, Ausubel's Advance organizers (Joyce and Weil 1980).

Looking from the empiristic point of view, the emphasis in learning is on concept formation with an experimental approach. Therefore, good starting points for creating suitable models of teaching are Bruner's concept attainment and Taba's inductive thinking (Joyce and Weil 1980). In physics it is often important first to find the experimental law acting in certain situation and then try to perceive the new concept which can be used in explaining and interpreting. This kind of approach has been applied in teaching the concept of density (Kurittu et al. 1988) and velocity on the secondary level (Kunnas and Ahtee 1991).

From the constructivist perspective, learning physics is an activity of constructing relationships and patterns because meaning cannot be transmitted. At school pupils construct their physics understanding in a social setting, the influence of which also has to be taken into account. In addition to individual writings, in which the pupils express their conceptions and reasoning, and whole – class discussions, in which the pupils share their solutions to enlarge and deepen their understanding, cooperative learning has shown to be very profitable. Wheatley (1991) advertizes problem– centered learning from the constructivist point of view because "favourable conditions for learning exist when a person is faced with a task for which no known procedure is available". He continues, "Problem centered learning with cooperative groups and class discussions becomes a rich environment for students' meaning making". Novak (1990) holds the use of metacognitive tools, like concept mapping and Vee diagramming, as the most powerful innovations for the improvement of education. The use of open investigations (Jones et al. 1992) could also be included within this category.

As to the teachers, they have to realize the level of understanding of their pupils. In my experience this is best achieved by asking the pupils to express in writing their ideas about different concepts and as well as their reasoning. A good form of in-service training seems to be to get the teachers involved in doing research about their pupils ideas. Thus, the teachers might change their implicit theories of the nature of knowledge and how pupils learn (Bell and Pearson 1992).

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Constructivism in physics teaching/learning

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The significance of constructivism has become central in the teaching/ learning of physics. It is consistent with the new concept of knowledge, according to which the construction and structure of knowledge are closely connected. Cognitive psychology, studies of the human brain and modern physics have advanced constructivism. Piaget's theory is one of its foundations. The processing nature of knowledge is emphasized when looking at the development of knowledge structures. A pupil's active part in constructing knowledge is very important in the process of learning. Knowledge includes personal and social aspects. A student's preconceptions has been one of the most important aspects in constructivism. There now appears to be a social mandate for constructivism. This report deals with the definition of constructivism and its application.

Introduction

The significance of constructivism has become central to the processes involved in the learning of physics, both here in Finland and abroad. Important contributors to this approach have been current theories of knowledge, according to which the construction and structure of knowledge are closely intertwined. Cognitive psychology (Piaget) and various studies of the human brain have advanced constructivism. The perception of the knowledge structure of modern physics has also advanced constructivism. There now appears to be a social mandate for constructivism.

Constructivism stresses the importance of the student himself/herself in the knowledge developing process. Thereby the processing nature of knowledge is emphasized when looking at the development of knowledge structures. Constructivism emphasizes student experimentation and problem solving methods such as the project teaching and learning cycle. The student's own activity and active participation are of central importance. Nevertheless, the significance of the teacher is not diminished, actually quite the opposite. His role changes from one who disseminates knowledge to one who presents different learning strategies and processes.

Constructivism can be used as a general term for new trends in education, and therefore there are several different orientations (Watts and Pope 1989). I wish to emphasize Piaget's significance in the birth and definition of constructivism. His research (begun in 1920) on the development of thinking in children was genetic, structuralist and constructivist. In this context another name could be mentioned, that of Ausubel (1963). The main principles of constructivism have been known for a considerable time. Fundamental in the current situation is that the principles underlying constructivism have been increasingly better founded (perceptions of knowledge, Piaget, brain studies), and now attempts are finally being made to bring these principles into practice. It means interaction between theory and practice. Application appears to be a long and tedious process.

I deal with my subject from a rather general point of view. It can be said that what I state on physics teaching is also valid in science teaching in general, and also in mathematics teaching.

On Piaget's theory and its importance to constructivism and physics teaching

I shall first mention some central principles of Piaget's theory, which in my opinion are also central principles of constructivism. I mean that physics holds an important position in Piaget's theory. In the construction of physical knowledge, the genesis of knowledge structures is a central issue. Therefore, a theory that deals with the genesis and structure of knowledge is useful in the teaching of physics. Piaget's theory has also influenced the current perception of knowledge.

Piaget's theory is genetic, structuralistic and constructivistic. It can be said that earlier structuralism was emphasized to a larger extent than constructivism. The significance of constructivism has constantly grown as the central role of the pupil him/herself in the process of learning has been recognized. However, it bears stressing that Piaget's theory, as a whole, forms a natural base for the didactics of physics and that constructivism is a natural part of it. The interpretations and applications of Piaget's theory have been debated, i.e. the genesis of the developmental stages. In general, however his theory has held its ground.

Piaget's genetic epistemology is concerned both with the construction of knowledge in the brain and the structure of knowledge, and these two are closely interrelated in his theory. It can be said, that genetic epistemology includes both an epistemological part dealing with the nature of knowledge, and a developmental–psychological part dealing with cognitive development. Many researchers regard Piaget's theory as primarily epistemological (Kubli 1983, 9; Sjøberg 1981, 5–8). The genesis of knowledge, its structure, predictability and validity are such epistemological questions.

According to Piaget, knowledge is built on experience, but it cannot be built solely on experience, as the positivists suggest. The subject's own activity is important in the genesis of knowledge. Even that, however, is not enough, as the idealists claim. Above all, knowledge must be seen as an ongoing building process, as more and more perfect knowledge structures are created stage by stage (Piaget 1974, 28). It can be said that Piaget's theory forms a paradigm of its own. His research methods resemble those of the natural sciences. Piaget's theory contains features from both empiricism and rationalism; it is thus related to Kant's philosophy (Sjøberg 1982, 75). On the basis of what has been said above, it can be stated that according to Piaget, knowledge is a structure that has been built up empirically and logico-mathematically in the brain. These structures represent our knowledge (Renner & Lawson 1973).

Piaget states (1972, 46) that there are physical structures corresponding to our operational structures. The structural similarity of these two structures, isomorphism, is thus included in Piaget's theory. According to Piaget (1974, 28), an objective reality that is not dependent on the observing subject does exist, but to know it perfectly is impossible. We can approach it as if it were a limiting value.

Piaget himself was not particularly interested in teaching and the applications of his theory. Yet his theory has become an important basis for the didactics of science. According to Piaget, knowledge means continuous construction, a process. As a result of this processing of knowledge, the pupil's knowledge structures become more and more complete, and his/her understanding of natural phenomena increases. The pupil constructs a conceptual description of the physics phenomena. Teaching has to be founded on the pupil's previous knowledge and adapted to his/her developmental stage. Teaching must also be founded on pupils' preconceptions. Since the 1920's Piaget's theory has emphasized the importance of the pupil's own activity in the process of learning. This is one of the central aspects of constructivism. In the so-called clinical interview, which is closely connected with Piaget's method, it is emphasized that the pupil should be given sufficient time to reflect upon natural phenomena. As for the teaching of natural sciences, the concepts of process and reflection imply that you start from an empirical basis and proceed with making inferences, analyzing, conversing with others and reflecting. There is no need for a strict separation of theory and practice. Good interaction between the teacher and the students, on the one hand, and among the students themselves, on the other hand, is a prerequisite for the genesis of thought operations.

The definition of constructivism and its application to physics teaching

I stress the construction and the structure of knowledge, which are closely connected.

According to the current perception of knowledge and to modern physics, our knowledge is based on our perceptions not on objective reality. So knowledge is a human construction. This idea is also included in constructivism (i.e. Driver 1989; Ekelund 1976 and 1989). The importance of this idea is also emphasized (i.e. von Glasersfeld 1990a and 1990b) in the didactics of mathematics. In general, it does not deny the objective reality, but we cannot get a sure knowledge of it. This view is from Piaget's theory, and many scientists base their study on genetic epistemology.

Knowledge is a human construction. It is not absolute and free from values, as does classical physics. Our knowledge, preconceptions and environment influence this construction. Thus knowledge includes personal aspects. Culture, the relations of scientists and values influence the construction of knowledge. Thus knowledge also includes social aspects. Knowledge is close connected to language (i.e. Driver 1989; Kuhn 1979). – It should be emphasized that deduction also plays a part in Piaget's theory and in constructivism. Induction and deduction must form a nonconflicting entity.

The student's own active participation is important in the learning process when applying constructivism. This may also be active thinking, not only experimentation (Gruber & Voneche 1977, 712). Driver (1989) says that learners are not viewed as passive recipients but are seen as purposive and ultimately responsible for their own learning. Teaching is not the transmission of knowledge but the negotiation of meanings. Many scientists present similar opinions, i.e. Kubli (1983 and 1989) and Sjøberg

(1981 and 1990). It has been commonly accepted that constructivism, and also Piaget's theory, represent so-called discovery learning. This implies learner and problem-centered methods, i.e. a learning cycle (Karplus et al. 1980) and project teaching. Research on students' preconceptions has been one of the most important areas in didactic research (Driver 1983; Driver, Guesne & Tiberghien 1985). In constructive teaching/learning one aim is to apply the outcomes of this research. The important parameter of successful learning is what the learners already know (Ausubel 1963). Kubli (1989) credits to Piaget the suggestions in his writings that efficient science teaching is a question of resonance with the student's spontaneous thinking. The experienced teacher knows the ways his students receive and assimilate information during his lessons. Kubli (1987 and 1989) also stresses the importance of emotional factors, especially when the students are girls. Research on the developmental stages based on Piaget's theory has been carried out, especially in England and the United States (Shayer & Adey 1981; Lawson 1985). To find out the developmental stage of the students, SRT-tests have been developed. There has been disagreement about the developmental stages. However, one may refer to the study by Adey, Shayer & Yates (1989) when attempting to develop the reasoning of the students. All these examples of the applications of constructivism are in correspondence with Piaget's theory. Sjøberg (1981, 4) states that the genesis of knowledge is also a theory of how knowledge is structured. Therefore, no structure exists without construction. Thus, the theory of learning is also a theory of knowledge, and vice versa.

The Finnish scientist Ekelund (1976) has developed, on the basis of Piaget's theory and constructivism, the experimental-inductive method. This method is a teaching method for defining the physical concept in upper secondary school physics. I have studied the practicability of the experimental-inductive method for about fifteen years (Seinelä 1987, 1989, 1991 and 1992). The experiment is part of my long-term work as a teacher of physics and a lecturer on the didactics of physics. These experiments indicate that physics provides a good context when applying constructivism to teaching/learning.

Finally, I would like to predict that, in the future, Piaget's theory, and thus also constructivism complemented by the results of the future research on the human brain, will form a good basis for research on the process of learning. This way we will arrive at a fuller picture of the nature of knowledge, which might also further the development of physics, especially the very serious problem of the interpretation of the theory of modern physics. It is natural because the brain is "the tool" when we construct knowledge. And Piaget's theory also has biological aspects. In any case, cooperation between many sciences is important in the future. Piaget himself was an expert in many sciences.

Discussion

Constructivism assumes a uniform system between research, the education of teachers and the school. It means a good interaction between theory and practice. The application of constructivism is an essential change in current practice, though many teachers nowadays use learner and problem-centered methods. Like Kuhn, we may talk about a change in the paradigm. And the change in attitudes is important. All this requires sufficient time, and we need flexibility in this process. However, constructivism seems to have vitality; many scientists defend it in scientific journals (i.e. Lawson 1993). The application of constructive principles in practice is still in its early stages. But I think that constructivism is useful when we develop the teaching/learning of physics in the future.

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The idea of space in geography

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The purpose of this article is to review the different conceptions of space underlying the work of geographers. Space is, as Couclelis (1992) argued, the most fundamental, because all other basic geographical concepts such as location, place and region are rooted in a somewhat different understandig of space. Concerning the spatial tradition in geography, we may speak of a hierarchy of spaces: mathematical, physical, sosioeconomic, behavioral and experiential.

Space, a concept with many meanings

Traditionally geography has been defined as a science that studies the earth as the home of man. Geography is also considered to be a specific "science of relations" and its particular object is to define the relationships between man and (natural) environment (Karjalainen 1983, 221).

The four main traditions in the field of geographical research are (Pattison 1973, 2): 1) the *spatial* tradition, 2) the *area studies* tradition, 3) the *man land* tradition and 4) the *earth science* tradition. The first-mentioned tradition is the oldest, although it has changed from a tradition focusing on determining the shape of the earth to a tradition with totally new contents and dimensions.

Basic concepts of geography are, e.g., *location, place, region* and *space*. Of these, space is probably the most fundamental (Couclelis 1992, 217). However, it is difficult to give an exact definition of this term since, unlike most concepts developed to refer to some specific thing or property of the real world, space seems to be part of the definition of that world. It belongs more in the realm of the philosopher and theorist than in the world examined by the empirical researcher.

Robert Sack (1980), who published a book on the different conceptions of space, chose as the basis for his conceptual scheme a twofold distinction between subjective and objective, on the one hand, and between space and substance, on the other. Conceptions of space that maintain these distinctions are in Sack's scheme called sophisticated-fragmented, whereas those that merge with them are called unsophisticated-fused. The spaces of science and social science are of the first kind, those of everyday life, myth and magic are of the latter. Many insights about the meaning of space emerge from such oppositions (Couclelis 1992, 216):

"Notions of space progress from more to less formal, from more to less well understood, and also from poorer to richer in human interest and meaning. The modern mathematician, the spacecraft designer, the industrialist trying to decide where to build a new factory, the urban commuter, the youth roaming the ethnic ghetto, the baby learning to reach for objects over its crib, and the mystic contemplating the perfection of a sphere all deal with space in its different manifestations. Indeed, we may speak of a hierarchy of spaces: mathematical, physical, soxcioeconomic, behavioral, experiential"

The significance of space as a geographical basic concept can already be seen in the geographical thinking of the eighteenth century philosopher, Immanuel Kant. He thought that geography was a corological or regional science, confining relevant space to the two-dimensional terrestric level of the earth's surface (Paasi 1983,64; 1993, 38-53). Although Kant's focus on Euclidean geometry (the only geometry known at the time) was later shown to be mistaken, his argument on the extra-empirical nature of space in general continue to be at the center of scholarly discussions of the concept (Entrikin 1991,90). Whether they follow Kant or not, geographers must come to grips with the idea of space and with a variety of related concepts, such as location, place and region. Each of those corresponding concepts is rooted in a somewhat different understanding of space, even though that understanding is usually tacit (Couclelis 1992, 216).

Quantitative concept of space in geography

The quantitative revolution took place in geography in the sixties. With the help of statistical analyses, models and system theories, efforts were made even to establish the common patterns of spatial behavior. It was then that the terms distance, direction, movement and reachability emerged in the language of space. Positivistic ideas of geography as a special science of space were expressed, e.g., by two Americans Blaut (1961) and Bunge (1962/ 1966). Of these two, Blaut can be considered as the pioneer of the modern geographical "space philosophy" (Paasi 1983, 83). He brought the concepts of absolute and relative space to the geographical spatial discussion. For example, places can be put on a map so that the distances between them are proportional to travel time or travel cost, which are in many cases more relevant measures of distance than the actual mileage. Already then Blaut (1954) was rethinking the language and spatial dimensions of maps, and later he made some studies on this subject, among children as well. Later on a Swedish geographer, Torsten Hägerstrand, suggested that distances away from a place are experienced logarithmically rather than linearly, with longer moves costing less than shorter ones.

Economic space, on the other hand, is defined by the spatial relations between consumers, producers, labour and raw materials. Therefore it is a relative space. Since the focus is on the relative location of human activities, geographers speak more generally of socioeconomic space (Couclelis 1992, 223). For example, all other things being equal, there will be more exchanges among places that are near each other than between places that are far apart, and more between large cities than between small villages. Spatial analysis and location theory are general approaches that use mathematics and statistics to derive the quantitative properties of socioeconomic space, trying to determine optimal locations for specific services, facilities or functions. In socioeconomic space, "optimal" means lowest-cost, least-time, least-effort, least-risk - generally speaking, least of something undesirable.

W. Bunge states in his work "Theoretical Geography" that geography is a science of spatial relations and interactions whereas geometry is the mathematics of space. Consequently, geometry should be the language of geography as well. In the middle of its quantitative revolution, geography almost drifted into some kind of spatial separatism (Smeds 1965, 36). Therefore, the strengthening of the humanistic and behavioral approach in the 1970's can be seen as geography's own counterreaction to excessive scientism and the increasing abstraction of concepts (Paasi 1983, 89). The focus of thinking started to move towards humanistic sciences and, on the other hand, towards the individual human level, giving again new dimensions to the concept of space.

Behavioral and experiential space

The nature of geography as a science that studies the interaction between man and nature indicates that human elements have always been part of geography. However, the birth of the true humanistic approach dates back no more than 30 years (Paasi 1983, 157). This hermeneutic, understanding alternative of geography developed in a way from the criticism of quantitativity.

On the other hand, cognitive behaviorism had already called geographers' attention to the "subjective" space, as perceived by people, in distinction with the "objective real world" (Sprout et al. 1957). However, behaviorists were not interested in either perception processes or factors causing distortion; on the contrary, the images and experiences of individuals were converted into data matrices which were then analyzed statistically (Gould et al. 1974/ 1986). The behavioral-empiristic approach was still, to a great extent, quantitative. Empiricists seemed to observe the outside world in order to find the "absolute truths" (Buttimer 1976).

In opposition to this "scientistic" approach, the goal of humanistic approach was to gain the understanding of the human world by studying the relationship between man and nature, people's geographical behavior and their feelings and ideas about space and place. The aim is to understand how the geographical functions and phenomena reveal the nature of man's consciousness (Paasi 1983, 161). For example, distances as experienced by people are not the same as distances on the map. Perceptions of how near or how far things are from each other are affected by the personal levels of knowledge of an area, by the psychological effects of habit, anticipation, fear, stress or boredom and by a host of other subjective or even biological factors. These perceptions, in turn, affect human behavior in space (Couclelis 1992, 225).

The key insight contributed by the approach known as behavioral geography is that people respond to environments largely as they perceive and understand them (Moore et al. 1976). Mathematically - optimal locations and routes are not necessarily the ones people will or should adopt. Behavioral geography recognizes two facts: first, individual behavior and decision - making in space are based on knowledge that is incomplete and distorted; second, complexities of human psychology lead to behavior and decisions that may not be optimal in a theoretical sense, but are considered best at the time by the individuals who make them

(Couclelis 1992, 226). According to behavioral geography, individuals act in a subjective world – a world in the head. The method by which this world in the head is studied is called cognitive mapping (Downs et al. 1973; Gould et al. 1974/1986). Another approach to the study of behavioral space is that of time geography, where individual movements are observed not only across space but also through time. A typical example of time geography is to write down, for mapping, a person's everyday routes telling where he has been and how long he has stayed in those places.

Also, the American pioneer of humanistic geography Tuan (1956, 1974, 1975) emphasizes the significance of the two concepts – space and place. But according to him, the main task is to explain the processes in the human mind through which space becomes a place. Space enriched with human experience and meaning has become a place. Tuan (1974) uses the term *"topophilia"* when talking about emotional connections between man and place, the intensity and forms of which vary greatly. Helen Couclelis (1992) defines experiential space as the space that human beings actually experience before it is passed through the filters of scientific analysis. It embraces all the intuitive or unarticulated forms of spatial understanding, the spatial experience inherent in the apperception of sacred and mythical spaces, as well as the aesthetic experience that is central to the creation and appreciation of art. In Sack's scheme this conception of space is called unsophisticated-fused because it seems to collapse the objective and the subjective, space and substance.

Most of the humanist geographers base their philosophical thinking on phenomenology and existentialism (Paasi 1983, 165). According to this way of thinking, space is seen as an egocentric concept, non-geometric, i.e. it gets its meaning through human experience. Nicholas Entrikin (1991) emphasizes that on a larger scale, existential space is an area the meaning and value of which can be mutual to a certain group of people, such as neighborhood or nation. Tuan (1974) also agrees that place knows no limitations, so it can be an armchair just as well as a national state.

What Pauli Karjalainen (1983) emphasizes is that the space between man and the world is the prerequisite for the fact that in general a connection can exist between an individual as a subject and the world as an object. He analyzes the concept of place in the following way (Karjalainen 1983, 223):

"Objectively, the place is the factual (measured) position of an object some - where. For example, in cartography the geographical location is usually given by means of meridians and parallels, in other words making use of an abstract spatial system. In this system a universal interpretation can be given to any place (position). Humanistic geography is interested in place as a site where people live, i.e. as a meaningful location, as internalized belonging to a place or – as it sometimes happens – as an alienated person's idea of belonging to somewhere else."

In the same context Karjalainen talks about the lifeworld, which is the basis for all experience.

The discussion on geographical space going on in humanistic geography shall be seen as a counterbalance to the physical-geometric space interpretation of positivistic geography. However, it went from one extremity to another in its criticism. All basic concepts of geography were individualized or psychologized as far as possible, in a way they were sacrificed on the altar of experience. A counterreaction to this has later developed among humanist geographers themselves (Entrikin 1991, 133).

Geographical world view

The view of the world and its formation have also been studied in Finland since the 1970's in several domains of science. According to psychologist Johan von Wright (1982, 6), the world view can be understood as *"an inner representation of the world which an individual constructs gradually with maturation, as a general view of his concept system concerning the outside world and his inner self which crystallizes everything he has learned, thought and felt during his lifetime"*. In a more concise sense, the world view generally refers to the information structures of the outside world (Paasi 1983, 451).

In these cognitive structures, knowledge and values are connected, even though at the research level the aim is to keep them separate. It is also possible to distinguish between spontaneous and learned views (v. Wright 1982, 7). School, in particular, is often considered to have the central role in transmitting and forming the world view (Rikkinen H. 1989, 141). To pedagogists the geographical world view usually means *"an individual's inner representations of the outer world's geographical elements"* (Paasi 1983, 453).

In any case, the idea of geographical space surrounding the individual has always been an essential part of the world view. In this context the world view is seen to consist, on the one hand, of micro-space, of which the individual gets information through his senses and, on the other hand, of macro-space, i.e. areas which are too large or far-away to be known in detail (Gold 1980, 128). The geographical world view consists not only of cognitive elements, such as the ability to sketch the continents of the world and the location of various countries, but also of images and opinions on the attractiveness of different areas (Rikkinen K. 1983, 18).

With age and experience every human being forms his own geographical world view, which has both egocentric and ethno-centric features. The farther off one moves from the everyday environment, the more superficial and haphazard the spatial basis of this view will be. Especially the images concerning the world-wide macro-scale space always have value elements and stereo-type views, mixed with the knowledge of different areas, their nature and culture. The individual usually "constructs" his world so that the appreciation of different areas quickly diminishes as the distance from the observer himself grows. A similar tendency has been noticed in the historical development of the map. (Tuan 1974, 42)

The process by which people perceive the location and interrelations of different areas and places is connected with their experience and cultural background as well as with the quantity and quality of the information given and received (Gould et al. 1986, 93).

Consequently, geography and its teaching are of vital importance in affecting one's geographical world view. Thus it is also important to know how the spatial basis of the world view develops as children grow up. This is the subject which the writers examine more closely in their other article on *"Mental maps in geographical research and teaching"*.

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PART II: RESEARCH PROJECTS

A case study on the teaching of optics on the ninth grade level

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This study gives an account of the planning and teaching of a unit on optics. It is an example of collaborative work between teachers and a researcher towards a change in classroom practice in order to strengthen pupils´ conceptual understanding.

Introduction

This study starts from the idea that teachers have to know how their pupils think about physics concepts. Physics teachers have a good basic education, they have studied physics at the university and have obtained a reasonable level in the knowledge of physics. Having reached this level, they seem to have forgotten the struggles they encountered in understanding different aspects and they tend to teach the facts and pay perhaps too much attention to deeper and more fundamental (more theory bound) questions which are interesting to them. They do not look at the situation enough from the learners´ points of view, who might have serious gaps or even misconceptions in their knowledge. According to the constructivist point of view, the learner has to actively construct his own conceptions. Learning just by listening, however clear and structured a lesson, is not permanent.

There are many factors which the teacher has to take into consideration when she wants to teach in a constructivist way. Such things as the pupils´ prior conceptions, the learning environment to support conceptual change like discussion, writing, arguing, co-operative learning, exploring, investigating, the kind of tasks and the order in which to take them up, and possible teaching strategies to be used in helping the pupils towards the physics way, using the concepts and explaining the phenomena (Scott et al. 1991).

Pehkonen (1994) considers the teachers´ beliefs about teaching and learning, which affect their way of teaching, as well as on what kind of content they want to concentrate. As the conditions for teachers change, the following aspects are brought up: (1) perturbance in teachers´ thinking, (2) commitment to do something and (3) a vision of the goal and the plan to realize it.

Setting

The school involved in this study is a large secondary school in the Helsinki area. On the ninth grade level the eight teaching groups, on the average, had 17 students in each group, altogether 139 pupils. Five teachers, three women and two men, taught physics on the ninth grade level. All of them had been teaching physics at secondary school for at least five years. One of them had not had teacher training. The teaching of optics took place in January and February. The teachers discussed together what and how they were going to teach. They decided with the biology teachers that the functioning of the eye should be taught integratedly immediately after optics. The teachers used from 9 to 16 lessons of 45 minutes to teach optics.

Background

All eight teachers who taught mathematics, physics, chemistry and information technology took part in the research project which had begun the previous autumn. When I contacted them in the spring of 1992 and introduced my research plans to them, they hesitated but promised to think it over during the summer. These eight teachers formed a fairly unified group. In the middle of the teachers´ room they had their own table around which they gathered. One of the teachers voluntarily saw to it that everything ran smoothly in the group. I was allowed to be present and tape some of the lessons. The teachers kept a log-book of the lessons.

During the research project the teachers had four longer training sessions about the constructivist view of learning and teaching physics. In addition, they had 16 hour–long discussion meetings. The teachers introduced their pupils tests on melting, boiling, dissolving, etc in order to find out and understand the variety of possible conceptions of different kinds of phenomena. All the teachers also studied the report about the conceptions of optical phenomena (Ahtee 1992).

Learning goals

As the main teaching procedure has traditionally concentrated on delivering information in the training sessions and discussion meetings, the main goals were to introduce the idea of teaching the pupils to think through the scientific enquiry method. The main way to get the pupils to reflect on and ask questions is through the example of the teacher. Therefore, an attempt was made to modify the teachers' way of asking closed questions with only one right answer to open questions which tempt the pupils to argue and reason about the possible responses. A good starting point was to let the pupils write briefly about their ideas and reasons for them. After that the cooperative group discussions and working strategies were prompted, as talking together might be easier in small groups and would, however, cover a lot of the central theme.

The contents were bound throughout as much as possible, to the pupils' own environment and familiar everyday things. In demonstrations and practical work simple equipments, which allowed for versatile qualitative exploration of the properties of the phenomena, were preferred, for example, to the ready made optical bench. These ideas were also implemented in the teaching material which was given to the teachers beforehand and which the teachers were urged to modify and improve before applying it in their teaching. The items discussed in the material were: Sources of light (Where does the light come from?), Properties of light (How does the light behave?), Shadows (How does the shadow form?), Stopping the light, Reflection, Seeing, Refraction, Formation of image by a mirror and by a lens. The teachers were given free hands to solve the problem of the time constraints. Some of them wanted to use more time on this topic, whereas some wanted to use more time on some other topic.

Carrying out the unit on optics

Table 1 gives a description of the first four lessons of two of the teachers. In the common discussion with all the teachers after the optics session Teacher A said that he had concentrated much more than earlier on the basic things. He had prepared written instructions for his pupils about the experimental problems to be used when teaching the reflection of light. This was also given to all other teachers. *"I enjoyed this lesson and the* *students also liked it very much.*" Teacher A clearly wanted to deal deeply with the nature of light with his pupils. He did not limit the discussions only to the macroscopic properties of light as did Teacher B. She had especially concentrated on looking at the macroscopic behaviour of light from as many points of view as possible. When planning the lesson she had written lots of questions in her log–book to encourage the pupils to think.

Table 1. Description of two teachers´ way of teaching optics.

	Teacher A 15 lessons	Teacher B 9 lessons
Tuning (How can you see an object?)	Pupils´ notes	Group discussions
Where does the light come from? 1st lesson	Common discussion —> excitations of atoms	Common discussion How far can you see? What stops you from seeing?
How does the light travel? 2nd lesson	Exploring with a flashlight Pupils suggestions for different models -> final choice, ray model demos with laser; speed of light; amount of light (practical work)	Exploring with a flashlight How can you test whether there is also light between the source and the light spot? Making pinhole cameras and using them
Shadows What happens when light meets an obstacle? 3rd lesson	Demonstrations with pupils´ help *"That was all we had time to do."*	Explorations and demonstrations Working with an optical bench
Reflection 4th lesson	Problem centered practical work	Practical work Pondering,writing. Seeing

Table 2 shows the results from two test questions introduced to the pupils after all the teachers had finished teaching the subject of optics. All the teachers gave their pupils the same test. The first task was taken from the work of Andersson and Kärrqvist (1981) with ninth grade Swedish students. The difference between the results of the pupils in this work and the Swedish ones is statistically the significant at a 5% level. Also, the difference between the results of pupils in groups A and B is statistically significant at a 5% level. Therefore, it is tempting to conclude that the pupils need time to adopt the basic principles in the behaviour of light And the more new facts they are given, the more things they have to handle. If the new things do not easily connect with the information structure, they might even instead disturb the construction of the easier ones. Therefore, it seems that at first time should not rush to give too much information and knowledge, but rather to give the pupils time to ponder and absorb all the new things.

Table 2. Results of two tasks introduced by five teachers (A to E) to the pupils after the teaching of optics, in percentages.

Task 1. How far do the car lights shine?(Andersson & Kärrqvist 1981)

Teachers	A	B	C	D	E	Average	Sweden
Amount of the pupils	46	24	24	17	28	139	166
Everywhere	50	75	46	41	25	48	32
Not far	41	21	42	53	39	39	53
No answer	9	4	12	6	36	14	14

Task 2. How could you determine whether a cat's eye (in the bicycle) is a light source or not?

	A	B	C	D	E
Dark place	61	83	50	53	54
Reflects	33	17	46	29	46
No answer	6	0	4	18	0

Teachers´ responses

Each teacher gave a detailed description of what and how he or she had carried out the teaching of the groups. In the common meeting all these practices were discussed. In general, the teachers had a positive feeling towards the project. They were ready to carry on with other similar projects next term, even though they had to work much harder in planning the new ways of teaching. In the beginning some of them were slightly afraid of how to deal with all the pupils´ questions. Now they appreciated the pupils´ reactions in different activities. For example, they pointed out that the pupils had been amazed when they noticed that the light from the flashlight reflected from their shirts to the surface of the table. On the other hand, the teachers also commented on the pupils´ reluctance to giving reasons for their answers. The pupils just wanted to know the right answer or solution. "*You can tell if that is correct or wrong.*" The project was closed for the rest of the term due to government cutbacks which forced some of the teaching groups to join together during different periods.

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Development of student teachers' environmental awareness in teacher education

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This article deals with the development of the environmental knowledge, attitudes and actions of the student teachers during their project studies. At the beginning of the project their interest and knowledge differed greatly concerning environmental issues. It was interesting to see the development of the process according to the constructivist concept of learning; knowledge and skills cannot be transferred directly to the students, but their own activity and own knowledge structures are decisive. After the first project year the students clearly assumed the responsibility for their environmental studies.

Introduction

The constructivist conception of learning is based on a dynamic conception of knowledge, which puts the emphasis on the learner's own activity to construct and process new knowledge. Learning is always context-dependent and social interaction plays a central role in learning. The teacher's duty is to organise learning environments, open systems based on constructive views in which learners can develop different kinds of models for thinking and processes. (cf. Glaser & Bassock 1989, Haapasalo 1993, Leino 1993, von Wright 1993)

In the fall of 1992, a two-year project of environmental education was started in the Department of Teacher Education at the University of Turku. Two of the main objectives of this research project are as follows:

* to study the process in which the environmental awareness, sensitivity, values and attitudes of student teachers developed through the project , and

* to study how actively student teachers attained for new knowledge and to construct it through the project.

What is environmental education?

"Environmental education is the process of recognising values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture and his biophysical surroundings" (Neal & Palmer 1990, 2). It also involves decision making and deals with issues concerning environmental quality (cf. Anon. 1991, Kajanto 1992).

Based on Hungerford and Volk's (1990,14) behaviour model, six critical education components of the environmental education are presented (cf. also Käpylä 1991):

1. ecological concepts
2. environmental sensitivity
3. in-depth knowledge of environmental issues
4. the skills of issue analysis and investigation
5. the citizenship skills for issue remediation
6. expectancy for acting in responsible ways.

Knowledge of ecology is an important variable in decision making, but this alone does not produce environmentally friendly behaviour. Environmental sensitivity has been found to be a very important variable. The knowledge variable and citizenship skill variable operate synergistically obviously, both being equally important. This positive reinforcement for environmental action is not easy to develop in the classroom. (Hungerford & Volk 1990, 11-12)

The environmental education research project

Seventeen first year students took part in the environmental education project. All of these girls were studying to become elementary school teachers. The project was carried out as meetings and in the form of tasks, done individually, in groups or co-operatively. The main assignments were carried out as two-week classroom projects.

During the first year, the project group had seven meetings, and a few more during the second year. Active discussion about environmental issues (the human nature relation, value education and different kinds of environmental projects) was one of the main purposes of the first meetings. In the last meeting, experiences of the classroom projects were carefully explored. The students also wrote reports on their project experiences.

These study objectives were approached using several qualitative methods. The material was collected in three ways: 1) by analyzing the answers to the initial test question: "What is environmental education and how could it be put into practice in the school?" 2) by the notes and observations made during the meetings and 3) by using project material produced in the classrooms.

Results and discussion

The majority of the variables found in the students' initial test papers were so called "entry-level" variables (cf. Hungerford and Volk 1990, 11). Everyone regarded knowledge and the training of attitudes as important parts of the education. About one third of the students wrote about the protection of nature, pollution and the basic knowledge of ecology. They wrote about "minor variables" or about the consequences of a nature-destructive behaviour. Only about 20% of the students mentioned "empowerment-level" variables. They wanted more information about the action possibilities and strategies. Only two students mentioned the concept sustainable development. To summarize, it can be said that at the beginning of the project the student teachers had highly conventional opinions. By providing them with knowledge, it is possible to change their attitudes in order to create more responsible environmental behaviour.

The project group was divided into four subgroups to make the individual and teamwork more effective outside of the meetings . Clear differences in attitudes and activity between these subgroups were already noticed in the second meeting. The upcoming project, not ready-made for them like "normal teaching", aroused both enthusiasm and embarrassment. Co-operational activities were considered to be very meaningful.

In January, during the fifth project meeting, the students clearly brought up their dissatisfaction with the project program. It seemed that they had not assimilated the meaning of the project at all. Students in some groups wanted excursions to some plants or institutes and others wanted to produce teaching material for environmental education. When the student groups received their own classroom project themes, about one month before their classroom teaching, they seemed reluctant, even aggressive.

Analysis of the student-teachers' classroom projects

The planning and initiation of the classroom projects. The student teachers experienced a great deal of difficulties in the initial phase. Good cooperative action was asked for. The schedule proved to be too tight. Also, the project themes should have been given out earlier. The students hoped to get to know the school and the classes for some time before starting the projects.

Conducting project work and integrated teaching seemed to be new and strange to the student teachers. They wanted more planning together, both with the class teachers and the project leader. However, the students worked hard, collected material and studied the subject matter of the projects. In some groups the project plan was successfully and quickly formed after an "initial chaos", in some others the plan took form in a gradual process. A great benefit for the groupwork was a good team spirit and a good ability to organize.

Earlier experiences with project teaching or learning were found to promote the project work in the classrooms. Project teaching demands very many qualities in the teacher: a planning and organizing ability, tutoring and evaluation skills, as well as motivation. Many of the student teachers found that there was a good chance for personal teaching during the projects. The pupils felt that excursions in nature, expert interviews, video programmes made by them and a nature film about Africa were the most rewarding. Although the planning of the project was hard for the students, working in the classrooms was easier, because the children were generally very enthusiastic about project work. The project was clearly also a success from the pupils' point of view.

Students' own project experiences. During the project teaching they had plenty of rewarding experiences. Almost all the final comments were similar.

> "The contract was hard, but sincere to be it was worth it." "Self-confidence and belief in one's own abilities increased considerably." "The project gave an opportunity to get away from the teacher-led teaching method and guided towards self-tu-

> toring work". "It awakened a new kind of interest in birds and showed the importance of environmental education".

One student strongly questioned whether it was reasonable to place project teaching into the first teacher training period. Most of the students, however, thought that it was a very good idea. Students' awareness of environmental education really increased while working on the project. One student did not leave her reflection report at all. She was working in the only group, in which co-operation did not work very well.

Conclusions

The concept of "environmental awareness" is here understood as the knowledge, skills and attitudes which are needed for responsible environmental behaviour. The need to behave responsibly is developing gradually through experiences. It is obvious that the objectives of environmental education are not achieved by the traditional school teaching. Integrating project teaching is necessary, as is getting out of the classrooms and also into nature. There is a need for becoming familiar with environmental issues, analyzing them and for getting knowledge and practical experience about citizenship action strategies.

The intenseness of the studies of our students caused many things to be passed over only superficially. To learn ecological principles and concepts almost simultaneously with having to teach them takes a lot of energy. In addition to this, the students had to practice different kinds of teaching methods. It was hard work but also very rewarding since it was a success. It seems clear that when the student teachers planned and carried out their environmental projects in the classrooms, at the same time they constructed deeply their own environmental awareness. According to the constructivist conception of learning, knowledge and skills are not transferred directly to other people, but rather that the learners have to construct their thinking through their own cognitive processes (cf. Lehtinen et al. 1990, 27).

At the beginning of the second project year the atmosphere of learning in the meetings of the environmental project had clearly changed. It seemed that the student teachers had taken care of their own environmental project studies. They wanted to know more about nature, ecology and the methods of environmental education. They were active in planning and carrying out the programme of their project. Sometimes the project leader felt that she could leave the student group to work alone.

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Can teaching in Finnish senior secondary school change pupils' beliefs

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The aims of this study was to investigate: How do students explain the two basic concepts and their applications in the area of heat science? The answers of the students were evaluated according to the aims of physics curriculum in which the kinetic theory of matter formed the basis of the understanding of heat and temperature. In the final year of the senior secondary school 38% of students could explain heat and 26% temperature as the physics curriculum expected. 57% could explain the application of thermal expansion of matter and 3% the application of vaporization.

Introduction

Students enter their physics classrooms with their own ideas and beliefs of many natural phenomena. These ideas and beliefs come from everyday life, from the students' own experiences, thinking and knowledge structure (e.g. Ahtee 1992, 8). The teaching itself can give new beliefs for students especially before the senior secondary school (e.g. Erätuuli 1987). There are numerous articles in the area regarding the students' beliefs of natural sciences (e.g. Duit 1987) and it is hardly interesting to search for more beliefs in the area of natural sciences. The next steps would be to study the effectiveness of teaching and different teaching methods to change students' beliefs.

The two basic concepts and two of their applications in the area of heat science were chosen as the object of this study. This phenomenon was chosen because these basic concepts of heat and temperature are very usual in everyday life as well as their applications, but the basis of understanding, the kinetic theory of matter is not so easy. Furthermore the physics curriculum requires an understanding of the chosen concepts of heat and temperature (Anon. 1982, 26).

The Finnish senior secondary school extends over a three-year period - in the near future there will be no specific grades and it may take from two to four years. There were three different groups of students: one group studied physics 8 x 38 lesson, the second 38 and the third not at all. In the future all students have to study physics for a minimum of 38 lessons and after that it is possible to choose more physics, up to 7 x 38 lessons. The heat science consisted of about 22 lessons and it was always during the first senior secondary year.

Problems and data inquiry

The aim of this study was to investigate: How students analyse the two basic concepts and their applications in the area of heat science and can teaching change pupils' beliefs? The questions were: **C1:** What is heat? **A1:** The iron ball goes through the circular hole in the room temperature but not after heating. Explain the reason for that. **C2:** What is temperature? **A2:** Before drinking a hot drink many people blow on the drink so that the liquid might cool sooner. Explain the reason for this.

This article is based on larger study combined with new data from the final school year.(Erätuuli 1984, 1987 and Erätuuli & Lechner 1992). In the earlier study (Erätuuli 1987, 1992) there were 152 students in group one (0) (after nine years of comprehensive school). About half of the age group continued their education in senior secondary school. About a third of the these students chose physics (8 x 38 lessons). In group two (1) were 272 first year students in senior secondary school and in group three (2) 140 third year students (about 18 – 19– years–old). The students were not chosen at random and therefore the results cannot be generalised. The new data 2 was collected in 1993, data 1 in 1992 and data 0 in 1987 and 1992.

Results

First the explanation models (for C1 and C2, A1 and A2) of the students who had studied physics in senior secondary school are analysed (see table 1). The ones who chose physics were normally better in physics in the comprehensive school. The bigger number of correct micro physical explanation models in the group of the first year students in the senior secondary school can partly be explained by the students' background. The ones who chose physics had a better previous knowledge of physics than those who had not chosen physics or the ones who didn't continue senior secondary school. The evaluation of the students' previous knowledge-level of physics was made during the last quarter of grade nine in the comprehensive school (0). Therefore this evaluation included the whole group.

Table 1. The part of the correct microphysical explanation models of the students who had studied physics

Concepts/ Applications	**0** %	**1** %	**2** %
C1	18	60	38
A1	87	95	57
C2	2	42	26
A2	1	16	3

At best, 60% of the students who had studied physics knew the correct micro physical model for heat (1). However the percentage sunk to 38 among the final year students (2). It is interesting that the correct micro physical explanation model for heat expansion (A1) was considerably well known. At the end of the comprehensive school, 87% (0) of the students knew the correct explanation and while having been taught thermodynamics in senior secondary school, it rose to 95%. However the end of the final year the percentage of correct explanations was however only 57%.

The common feature for all wrong models of heat expansion was the mixing up of electrons with molecules and atoms. Besides this common explanation model other individual models were missing among answers of the final year students. Among the models of the comprehensive school students and the first year students there were still some very differing models.(see Erätuuli 1992, 12-17).

The explanation models for the temperature and acceleration of the cooling down of a drink, formulated by the students studying physics in senior secondary school are shown in table 1. In the final year of the senior secondary school only 26% of the students could explain temperature correctly, whereas 42% could do it in their first year. At the end of comprehensive school only 2% gave the right explanation.

The wrong explanation models at the end of senior secondary school were the same as in the beginning (see Erätuuli 1992, 14). The application of speeding up the cooling down proved to be very difficult throughout the senior secondary school. At the end of senior secondary school only 5% of the explanation models contained the correct micro physical model. By far the most common wrong model was that the blown air was colder than the drink and therefore the drink cooled down. More than half of all explanation models belonged to this group.

Table 2. The correct microphysical explanation models of students who had no physics in senior secondary school

Concepts/ Applications	**0** %	**1** %	**2** %
C1	25	20	20
A1	45	44	47
C2	2	3	9
A2	1	3	5

Table 2 shows the percentage of the correct explanation models for C1 and C2, A1 and A2 of the students who had quit physics. Among the first year students there is an apparent small decline in the percentage of correct models. Heat can be explained by a fifth of the students who were not studying physics but heat expansion by 47%. The difference between the final year students as compared to the previous group was 18 in unit of percent. On the other hand, at the end of the senior secondary school almost half of the students who had not studied physics could explain heat expansion with the micro physical model. The difference compared to the students who had studied physics was 10 in unit of percent.

At the end of the senior secondary school the students who had only studied physics in the comprehensive school could give the correct explanation models for temperature and the speeding up of the cooling of a drink in 9% and 5% of the cases respectively. The improvement compared the end of the comprehensive school was a few unit of percent. The difference between the percentage of the correct models for temperature by students who had physics in the senior secondary school and those who had not was 17 in unit of percent at the end of the senior secondary school, and 39 in unit of percent in the first year (1).

Discussion

What is teaching like in the Finnish senior secondary school? In their answers teachers tress lecturing, teachers' questioning, calculation and demonstrations. The teaching of physics in the comprehensive school is mainly based on laboratory work. Almost all students have learned the application (A1) of heat expansion in the form of laboratory work, or at least seen it as a demonstration. Also, the micro physical model of heat was part of the teaching in comprehensive school. However, not until being taught in senior secondary school did more than half of the students understand the micro physical model. Almost all students could explain the application. The level of explaining the application was still satisfactory in the final year of senior secondary school.

Understanding temperature applying the micro physical model was never a goal in the comprehensive school. This is shown by the extensive increase of correct answers after being taught the subject. in the senior secondary school. However, the difficult application was only mastered by 16% immediately following the teaching of the subject. It was forgotten in the final year of the senior secondary school. When looking at the differences between the students who had studied physics in the senior secondary school and those who had not chosen physics, they were fairly large in the end of the first year but became smaller at the final year. The differences in the percentages are: C1: 18, A1: 10, C2: 17 and A2: 2. This percentage indicates the increase in the number of students who could explain the concept and its application using the micro physical model. The differences are significantly greater immediately after the teaching of the subject, being respectively 40, 51, 39 and 13 percent.

The answers of the students told that the teaching was not very effective or the kinetic theory of matter was too demanding. The differences between the students who had studied physics and the students who had not studied physics in the senior secondary school told that teaching physics was of significant importance, but could not give permanent results.

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Model for construction and assessment of conceptual and procedural knowledge

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For mathematical constructions we have to provide children with opportunities to learn concepts and structures, not only context- oriented knowledge and routines. In the **MO-DEM** project (**Mo**del Construction for **D**idactic and **E**mpirical Problems of **M**athematics Education) the learning of mathematical concepts has been investigated within "systematic constructivism". The article introduces a model for constructing and assesssing mathematical knowledge from this point of view, where the acquisition of mathematics is seen to be based on conceptual knowledge.

The framework of systematic constructivism

The first element of the systematization consists of separating mathematical knowledge into *concepts, theorems and procedures*. We try to give the pupil a sufficient number of opportunities to construct concept attributes and procedural knowledge based on them. In order to complement this, we have to be ready for a long process of concept building in which we separate the phases of *orientation, definition, identification, production* and *reinforcement*. This is the second element of systematization (Fig. 1).

Because in constructivism the pupil is considered to be a subject who is actively forming, processing and retaining information, it requires us to see acquiring knowledge as a dynamic process which is executed in a situation that is meaningful for the pupil. Contextual problems which the pupil can interpret through his mental models can be used for *concept orientation*. It is important to know the usefulness of different kinds of problem typologies by problem posing, like Dörner's classification: dialectic, interpolation and synthetic problems (see e.g. Kretschmer 1983 and Fig. 2).

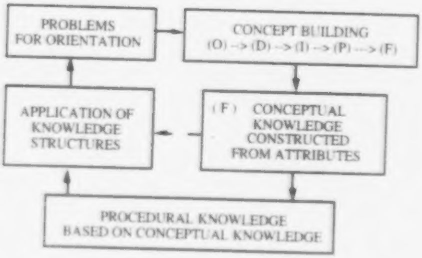
PROBLEMS FOR ORIENTATION
CONCEPT BUILDING (O) --> (D) --> (I) --> (P) ---> (F)
APPLICATION OF KNOWLEDGE STRUCTURES
(F) CONCEPTUAL KNOWLEDGE CONSTRUCTED FROM ATTRIBUTES
PROCEDURAL KNOWLEDGE BASED ON CONCEPTUAL KNOWLEDGE

Fig. 1. Construction of mathematical structures within systematic constructivism

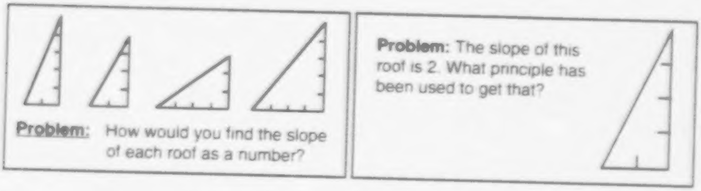
Problem: How would you find the slope of each roof as a number?
Problem: The slope of this roof is 2. What principle has been used to get that?

Fig. 2. A dialectic and an interpolation problem for orientation to "gradient"

A dialectic problem-posing provokes the pupil to interpret the situation with his own mental models (Fig. 3). Because these are the only relevant interpretations of the situation, especially at first, we have to accept a radical constructivism according to Glasersfeld (1991). On the other hand, *radical constructivism is only elevant locally during a certain learning period*, because the mental models (concept attributes) of different children should match each other reasonably precisely after the learning period. The difficulty of identifying weak and radical constructivism can be lightened by using a metaphor from professional tennis. The external global terms mean that we know when and where the final is going to be played. We can even make assumptions about tactics to be used by the players, if the matches are played on grass, for instance. But we never know who is going to play in the final, and how the finalists are going to qualify. Thus, especially*locally*, we have to accept very radical changes, tactics and even results. The systematic constructivism of the MODEM -project could be described as a *local constructivism* which allows the child to make very radical and individual, even naive and context-oriented mental models in local situations on the way towards more acceptable social and cultural models, concepts.

Finding a *definition* for the concept should be mainly *a process of social construction,* where pupils try to fix the relevant determiners of the concept (Fig. 3). In the phases of orientation and definition, creative thinking and productive work by the pupil is needed.

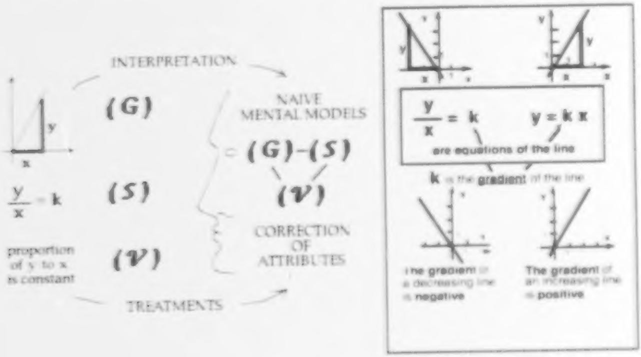
INTERPRETATION
(G)
(S)
(V)
y
x
y/x = k
proportion of y to x is constant
NAIVE MENTAL MODELS
(G)-(S)
(V)
CORRECTION OF ATTRIBUTES
TREATMENTS
y/x = k
y = k x
are equations of the line
k is the gradient of the line
The gradient of a decreasing line is negative
The gradient of an increasing line is positive

Fig. 3. Construction of the relevant attributes of the concept "gradient"

In the phase of *identification* we have to give pupils possibilities to train the identifying of concept attributes in verbal (V), symbolic (S) and graphic (G) forms. For this we need six kinds of identification tasks (I): IVV, IVG, IVS, IGG, IGS and ISS (e.g. IGS denotes an identification between graphic and symbolic forms in Fig. 4). During the learning process the teacher must be ready to begin with tasks that require distinguishing between only two elements before going on to the identification of several elements.

In the phase of concept *production*, we have to give pupils possibilities to produce, from a given presentation of the concept, another representation in a different form. The development of production (P) requires nine combinations: PVV, PGV, PSV, PVG, PGG, PSG, PVS, PGS and PSS (Fig. 5). The tasks of identification and production must be achievable without any complicated processing of information on the student's part.

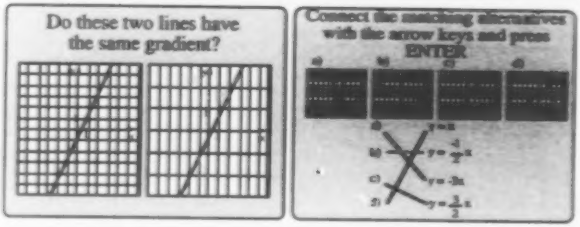
Do these two lines have the same gradient?
Connect the matching alternatives with the arrow keys and press ENTER
a)
b)
c)
d)
y = x
$y = \frac{-4}{2}x$
y = -2x
$y = \frac{3}{2}x$

Fig. 4. Simple (IGG) and more complicated (IGS) identification tasks

In the *phase of reinforcement* the goal is to train concept attributes and to develop procedural knowledge to be used in problem solving and applications (Fig. 1). When assessing the learning results, the same type of tasks are called either application tasks or mechanical tasks (Fig. 6).

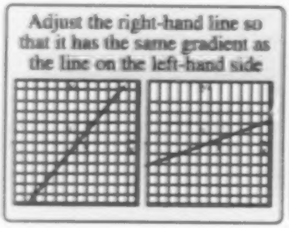
Adjust the right-hand line so that it has the same gradient as the line on the left-hand side

Fig. 5. A production task PGG

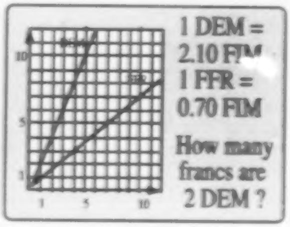
1 DEM = 2.10 FIM
1 FFR = 0.70 FIM
How many francs are 2 DEM ?
10
5
1
1
5
10

Fig. 6. A reinforcement task

The empirical research

In the MODEM 1 the learning of the gradient of a straight line was studied by means of a learning program (Haapasalo 1991, 1989). In this program each phase of concept building is programmed as an independent module and may also be used as a stand-alone program. The main menu allows one to choose any module or an alternative, in which the program automatically takes care of all five modules. The order of the modules and tasks in each module can be changed for carrying out a study of the meaning of each subphase. Eight grade pupils learned in two hours, assisted by the computer alone. For subgroups a certain module was skipped.

πIn the MODEM 2-3 (Haapasalo 1992, 1993) the experimental group in the 4th grade learned fractions (resp. decimals in the 5th grade), and the comparison group was taught in conventional way.

The assessment was planned so as to measure all combinations of identification and of production, the role of different forms of representation, the importance of different phases of concept building and the ability to use concept in simple applications.

Summary of the most important results

The investigations confirmed that the process of concept building is for most of the pupils a long process in which the above subphases are systematically involved. They also form a good framework for assessment. The identification phase plays a central role in concept building, and seems to give the pupils the best and most pleasant learning environment for the forming of concept attributes. Skipping it, or even moving it into a wrong place after the production, caused a lot of difficulties in concept building. Pupils' cognitive results were significantly poorer and their opinions of the learning significantly more negative than those who learned with identification. However, skipping the production did not cause any statistically significant differences in the cognitive test, but had a positive effect on the pupils' opinions of the learning!

Concept understanding is measured most reliably by the production tasks, but unreliably as well by mechanical and application tasks. Production tasks are also difficult for the pupils. The tasks containing verbal representation are systematically difficult and have high reliabilities by the measuring of concept understanding. A production within the same representation form is significantly more difficult than a production between different kinds of representation. The same did not hold for identification. Mechanical tasks had a poor correlation with each other and with other tasks. In MODEM 2 every application task had a corres-ponding mechanical task at the end of the test requiring the same arithmetic operation. Fig 7 shows that, in spite of the large number of mechanical tasks in textbooks, the performance of the comparison group on such tasks was poorer than the performance of the MODEM-group, which did not have any drilling at all. The learning within systematic constructivism not only lead to significantly better results, but the pupils (especially the boys) also liked these kinds of learning environments. The teachers confirmed the fact that perseverance and consistency in the pupils' work clearly also improved in other subjects.

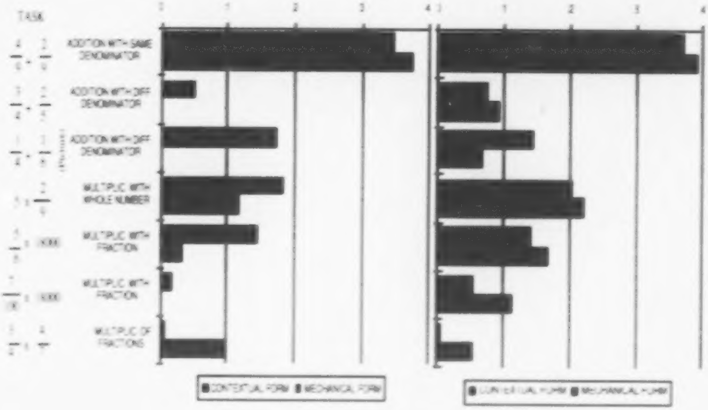

Fig. 7. Pupils' performance in mechanical and corresponding application tasks with fractions. (left: comparison group, right: MODEM -group)

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Mathematics on the Child´s Condition - a Constructivist Approach at School

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1987 a project in mathematics called the ELMA-project (The Project of Pupil-adapted Teaching in Mathematics) was started at the Department of Education and Vasa Övningsskola (a teacher - training school). The aim of the project has been to describe and develop theories and methods for the instruction and learning of mathematics for children aged 7 to 12. New methods in mathematics tuition and learning procedures have been composed within the project, which has resulted in the pioneering of new textbooks and teaching aids.

The background of the project

The projectwork commenced with a survey of the pupils´ mathematical skills at the schoolstart. We noticed a clear contrast between the children´s experiences and needs and the instruction that traditionally is practised in our schools. Our interest was aimed at planning instruction which would utilize and develop the informal knowledge in mathematics that the children presented. The child and learning theory that became the tendency within the project was based on a cognitive learning theory.

Learning is an active process that leads to a permanent change in a person through the experience that person possesses. Experience is gained through interaction between perception and action with concrete objects, while language also has a strong influence. In the learning process, the pupil increases his supply of knowledge by construing new knowledge which merges with the pupil´s existing information system.

According to constructivism (von Glasersfeld 1987 12-13) learning is an active, constructive and goal-orientated process which occurs in the pupil´s own environment and is adjusted by the pupil himself. In order to emphasize that the pupil´s education is incorporated in a social context, the concept social constructivism (Björkqvist 1992, 111) is used.

Through social constructivism interaction between society's knowledge and the development of the individual's knowledge is gained. Mathematics is viewed as both an individual and a social construction. The child's ability to be an independant active part in the learning process is credited, and the importance of cooperation with the surrounding is realized. The important role of the teacher in the learning process is emphasized. When the instruction methodology had been developed and tested within the project, we proceeded from some didactical principles that we found characteristic for a constructivistic learning approach.

Knowledge development in the child's condition

The language, experience and knowledge of the children have been influenced and formed by the society and the environment around them. Their spontaneous conception of their surrounding world is created at an early stage and children interpret and prioritize the significance of the surrounding information. The mathematical knowledge that children have developed by the time they start school varies a great deal, depending on the experience and the intellectual development of the child.

The task of the school is to maintain and further develop this knowledge by providing the children with versatile possibilities to work with their experience. In the children's world of concepts (Johnsen Høines 1990, 25) there is an important foundation for preparing and carrying out instruction. By getting acquainted with, developing and showing respect for beginners' knowledge, we find the right starting-point for work. The methodology for instruction that has been tested within the project is aimed at giving each child the possibility to develop, according to his own qualifications to attain good mathematical skills. In the learning process, the activity of the pupil is of central importance. Learning from this perspective means that the children interpret their experiences and develop their own thought structures through active engagement and concrete experience.

We have strived for the means to work in which we preserve the pupils' experience, supply their needs and help them to develop into independant individuals. Our aim is to give children a possibility to experience mathematics, as well as an aid to describe the surrounding world as an intellectually challenging subject, a subject which offers activities for playing and games.

Already from the first school year, the items are formed so that the pupils´ individual characteristica stand out and they get accustomed to working on different levels. The individualization facilitates the help of repetative work routines. During the first two school years the children work in a pupil´s book allowing for the pupils´ thoughts and knowledge. In the pupil´s book the children write down their mathematics, which emerges from their own interpretations and experiences. The pupil´s book is filled with colourful illustrations and forms of thought; it reflects a type of mathematics that is developed from interaction with instruction, the surrounding world and the experience of the child. The book is important for the child, who continously follows its creations and is eager to show the results. When the pupil writes his mathematical stories and counting narratives a close connection exists between concrete reality, a written text and the mathematical symbol language.

Social interaction and language use

Mathematics education is an active process which is developed in interaction with other people and which occurs in the social interaction developed in the classroom. In the instruction we use activities which promote both individual and social development. In trying to root mathematical concepts in the children´s thoughts and experiences, they are confrontated with everyday and realistic problems and situations. Through investigative working methods and laborations, the pupils are offered the possibilities to discuss together alternative models and suggestions for solutions. An active use of language promotes the learning of concepts. Language and concept formation are mutually developed through an increase of the child´s understanding of a concept and the concept perception encourages them to use a more versatile language. A well-developed concept perception means that the pupil both, orally and, in writing, should be able to use the concept, enlighten the concept with a picture and a concrete model, and be able to use the concept in everyday situations (Lesh et al. 1987, 34). Starting from a concrete reality the pupils build up a mathematical model and activly use the language simultaneously. Language is the bridge leading to abstract thinking. With the help of symbols, the pupils write down the language they use and form an algorithm or a formula.

Concretization and connection with reality

Mathematics has an abstract nature but is developed from concrete happenings and a need for solving practical problems. In school mathematics, the abstract nature and logic system of the figures is connected to practical applications and problem solving. The children are assisted in understanding mathematical structures by investigating and working with real things. It is important that the children experience that the material illustrates the presentation of the problem and becomes a part of the thinking. The material becomes the instrument of thought. The greater the experience the children get, the easier it is for them to interpret conceptions of reality expressed with symbols, the mathematical language. Concrete work may mean, among other things, to build and investigate models, to start from practical situations and happenings that are familiar to the pupils and to investigate connections and relations.

By listening to the spontaneous comments of the pupils, we gain knowledge about their forms of thinking and we can help them to develop new structures. The individual work is layered with common practises or discussion in small groups (Davidson 1990, 53). The pupils discuss about forms of thinking a specific subject-matter, solve thought-related riddles or formulate common items.

The role of the teacher

The role of the teacher in the instruction process is reflected in the view of cognition that the teacher represents, and in the choice of knowledge prioritized and the chosen strategy considering the different qualifications and experiences of the pupils. We have to focus our aims on children´s thinking (Kamii 1990, 27-28), rather than on writing right or wrong answers. We must encourage the pupils to discuss different solutions rather than reinforcing the right or wrong answer. If we know which solution-strategy a child is using, we can help the child to correct a form of thinking which is not applicable.

The task of the teacher is to create a favourable learning environment which results in quality work and which gives security and satisfaction to the children. The following components represent some characteristics of a favourable learning environment:

The experiences of the pupils as a starting-point for work. The treatment of the pupils is characterized by respect for the different starting-points of the pupils as well as by school-start and during work in the learning process.

Reasonable demands and expectations for each pupil. Bad interaction between the maturity factor and the learning programme can lead to deficiencies in the pupil's conceptual perception.

The children have time enough to complete work carefully. Through an individualized workpace, the children are given the possibility to proceed at their own pace.

The pupil is given attention and his work is appreciated. The work children do is valuable and appreciated.

One of the most important duties of a teacher is to create a positive learning environment which encourages creative and active work. How should the classroom be decorated to allow for social interaction, undisturbed indivudual work and, in addition offer opportunities for the flexible use of versatile learning material? The pupils experience mathematics as an aid for describing our reality. The role of the teacher is not to teach concepts, but to affect the pupils' thoughts of concepts. By putting the pupils in cognitive conflicts, situations are created which activate the pupils and develop reflections and thinking processes. Mathematical knowledge develops from interaction between the concrete experience and reality, between the hand and the thought, between the individual and the community.

Conclusions and reflections

The development work has raised many questions and thought-provoking discussions. To change the instruction of mathematics is to analyze your own way of thinking and acting.The constructive theory of learning requires a pupil-centred way of working. The relation between concept learning and proficiency practise, usage of technical aids, mental arithmetic and written disposition have been discussed.The work method puts new demands on assessment. Allowing pupils to investigate mathematical concepts themselves is time-consuming and requires good organizational skills from the teacher. Through process-directed activities, the instruction has been formed from the need and inner structure of the class. In mathematics instruction, the teacher´s professional knowledge and the individual needs and activity of the pupils are united. Increased knowledge concerning children´s learning, respect for the individual and good subject knowledge are requisite for successful work.

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Learning physical concepts using real-time microcomputer-based laboratory tools

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We are developing new microcomputer-based laboratory tools for data acquisition and analysis in science teaching with the interface of IBM PC/AT/PS computers. Our new software, version 3.0 of the Empirica, runs under the Microsoft Windows 3.1 Graphical Environment and it allows for several methods of data analysis and graphical visualisation. A pedagogical research and development program has also been initiated to produce teaching materials as well as different practical approaches to the problems of teaching-learning situation in schools.

Background

Over the last few years many studies have been made on how pupils of different age groups predict and explain natural phenomena. The main result of these investigations is that pupils' conceptions of natural phenomena are markedly different from the concepts which usually underpin teaching programmes. In order to solve this problem, we need teaching strategies which induce students to make changes in their beliefs about how the world works. Such strategies have to address both instructional methodology and content. Some that appear to be effective are already being developed and tested (Adey 1993, Driver 1989. 484, Novak and Gowin 1983). All this strategies are conceptual change strategies (Hewson and Thorley 1989).

Interaction between nature and present knowledge. In our research we attemted to develop a laboratory tool which could be used for conceptual change. (compare Thornton and Sokolff 1992). We believe that learning is an active process in which the learner constructs his or her own personal world view. What is learned in any new situation depends as much on the ideas the learner brings to the situation as on the learning situation; learning is a result of an interaction between new situations and present knowledge. When pupils use microcomputer-based data acquisition they can easily repeat an experiment and investigate how the situation changes when they change one parameter. They can also easily investigate how their suggestions work in the real world.

In physics teaching, modern learning theory means that we have to use an experimental approach, which is the natural way of teaching physics. The starting point in teaching is the observation of a phenomenon in nature. After recognition of the phenomenon we may obtain quantitative knowledge of the phenomenon by observation or measurements. Concepts and natural laws can be defined by presenting invariances between entities. The theory and the laws may then be applied when we are analyzing new phenomena.

The role of the computer in the experimental approach is the data acquisition, graphical presentations, analysis of the data, modelling etc. All these help pupils to understand new concepts and natural laws. It is important to realize that perception of the concept or law is part of the process of the pupil, not of the teacher nor of the computer (eg. Kurki-Suonio 1993). Each processual element has to be learned by the pupil. He has to learn to observe, measure, plan and realize controlled experiments, do experimental research and conceptualise observations, present results, interpret, model and predict. Therefore, computerization should not proceed too fast. Only processes already learnt by the pupil can be automated without violating natural learning. (see also Peacock 1990, 6 - 34, Erätuuli ja Meisalo 1991, 4)

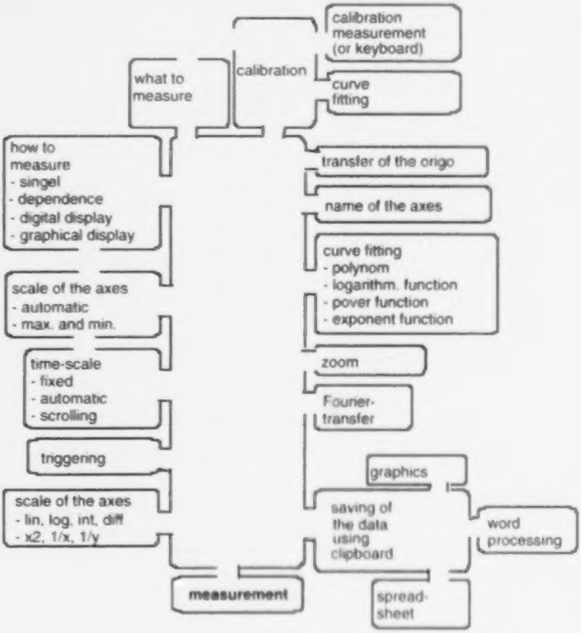
Human interaction. When we use computers in teaching, we have to understand that they are not the single solution to better education. We must understand that when we are interacting with nature, the computer is only a tool. When we use microcomputer-based data acquisition, we save time in our interactions with nature, and we can thus increase human interactions (see Meisalo and Tella 1987, Erätuuli and Meisalo 1991).

The teacher can increase human interaction by applying the following methods:

- The teacher must learn to ask questions that lead the pupils to fully articulate the interpretations and explanations in their own words.
- The teacher must demand that his pupils describe their observation in their own words prior to using the terms that science has chosen for these same observations and concepts.
- The teacher should ask his pupils to use the concepts in a more extended manner and in new contexts.

- The teacher has to teach basic skills which can be applied to any scientific investigation. These basic skills are: asking questions, observing, classifying, recording, interpreting, analyzing, concluding, suggesting explanations, predicting, making test (fair), applying ideas and so on (e.g. Peacock, 1990, Arons 1990).

"Extended market square" metaphor


calibration measurement (or keyboard)
what to measure
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name of the axes
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- polynom
- logarithm. function
- pover function
- exponent function
scale of the axes
- automatic
- max. and min.
zoom
time-scale
- fixed
- automatic
- scrolling
Fourier-transfer
triggering
graphics
scale of the axes
- lin, log, int, diff
- x2, 1/x, 1/y
saving of the data using clipboard
word processing
measurement
spread-sheet

Figure 1. "Market Square" as metaphor for developing software.

In our research we strongly feel that when we utilize computers in science teaching emphasis has to be placed on direct observations and experiments instead of an computer simulations. Physics teaching should be based on direct observations and experiments, with the computer included as an integral part of the school laboratory. When we use computers in science, teaching the learning environment can be described through the "Extended Market Square" model (Meisalo 1991). The Market Square is not restricted to a computer, but is broachened to include Nature itself, even outside the school such as experienced during field trips and other practical activities and projects. Computers are used as tools as teachers and pupils work towards defined goals. This model illustrates the possibilities for open new approaches and creative problem solving. Pupils and teachers should be free to use a wide variety of instruments and tools for their investigations.

We also utilized the "Market Square" as metaphor when we developed our software (see Minken & Stenseth 1992, 41). Pupils could select tools from drop down menus or dialogues and get the measurements from the selected windows.

The data acquisition system and software

In 1987 we began using the computer as a laboratory instrument in our physics courses and started to develop interfaces and software. We are now working with Empirica software for Windows. The Empirica measurement program is an interactive program which includes a package of tools for data manipulation. Files can be transferred to spread sheet, word -processing or graphics programs.

The data is transferred from the measurement sensor to the computer through an *Empirica* Interface connected to the RS-232 serial port. *Empirica* Interface has ten measurement channels, a resolution of 14 bits, the sampling rate of 100 kHz, a transient recorder (triggering either from a rising or falling measurement signal with the wanted offset valence) (Lavonen 1993).

Example of using a computer in experiments

In this example we describe how the concept of resistance is defined with the help of observed invariance in the structure of phenomena. We built a closed circuit of voltage supply, wire and ammeter. In the experiment we needed a voltage supply that could be increased smoothly. We measured the voltage and the current through a wire and presented the data graphically. In the next measurement we used a longer wire. We always got a straight line. The slope of the straight lines was a property of the wire. In this case, the property was called resistance. Resistance was independent of the current. Resistance was dependent on the length of the wire. The slope was bigger when we had a longer wire. The data could be studied in detail by using the spreadsheet Excel.

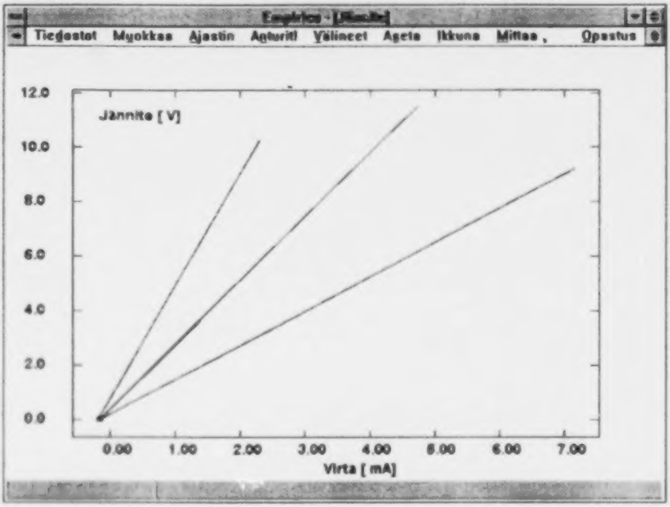

Figure 2. Concept of resistance.

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Teachers' Conceptions about Mathematics Teaching in Comparison (Estonia–Finland)

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Firstly, a brief description of the comparison study between teachers' mathematical conceptions in Estonia and Finland is given. Secondly, some preliminary results are discussed concerning teachers' conceptions in the framework of Dionne's (1984) three perceptions of mathematics. The Estonians seem to have a more formalist perception of mathematics than the Finns.

Introduction

In this context, we understand beliefs as an individual's subjective knowledge of a certain object or concern for which knowledge there may not necessarily be any tenable basis in objective considerations. Furthermore, we may explain conceptions as conscious beliefs, i.e. we understand conceptions as a subset of beliefs. For a more detailed discussion of "belief" see Pehkonen (1994).

An international comparison of teachers' beliefs. The findings dealt with here are based on a comparative study which was carried out during the years 1987–90 and explored teachers' conceptions of mathematics teaching in middle schools in Estonia and Finland.

In the questionnaire[1], there were 54 structured items about different situations in mathematics teaching. The teachers were asked to rate their views within these statements on a Likert scale (1=fully agree, ..., 5=fully disagree). At the end of the questionnaire, there were four open-ended questions about the main difficulties in realizing mathematics instruction.

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[1] Bernd Zimmermann (Hamburg) developed the questionnaire for the research project "Open Tasks in Mathematics" (cf. Pehkonen & Zimmermann 1990).

The data was gathered in two different ways (EW = Estonia, FIN = Finland): One part of the sample consisted of teachers on in-service courses ($N_{EW} = 76$, $N_{FIN} = 52$), where the questionnaire was filled in at the beginning of the course. And the other group of teachers were reached by mail ($N_{EW} = 30$, $N_{FIN} = 34$), i.e. the questionaires were sent to them. Thus, there were altogether 106 responses from Estonia and 86 responses from Finland.

The focus of this paper is to answer – at least partly – the following specific question: What differences are there in teachers' conceptions in Estonia and Finland?

Some preliminary results

For his research work, Dionne (1984) developed the following three perceptions of mathematics: The traditional perception of mathematics means calculations and following rules. The formalist perception of mathematics stresses rigorous proof and exact use of language. The constructivist perception of mathematics puts pupils and their needs in the first place, and therefore emphasizes the use of pupil-centered teaching methods.

When discussing the 54 statements of the questionnaire, we succeeded to classify about two thirds of them into these three perceptions. In doing this, we have made only such selections in which we have agreed with each other that the statement belongs only to one perception. Thus, we got the following three subscales:
the traditional perception (items 5, 8, 10 24, 26, 29, 31, 34, 41, 43);
the formalist perception (items 1, 4, 7, 11, 12, 13, 17, 19, 33, 35);
the constructivist perception (items 2, 6, 9, 14, 16, 18, 20, 28, 36, 38, 40, 42, 44, 45, 47).

Altogether 19 statements were left outside of these three perceptions of mathematics, since we were not able to place them into any of the perceptions, or we were not in agreement about their place.

The traditional perception. There are 10 statements in the traditional perception of mathematics:

		EW	FIN
5.	In a mathematics lesson, there should be more emphasis on the practicing phase than on the introductory and explanatory phase.	2.29	1.76
8.	Pupils should learn above all to have a command of the basic techniques of calculations.	1.46	1.55
10.	In mathematics teaching, one has to practice much above all.	1.60	1.63
24.	The learning of central computing techniques (e.g. applying formulas) must be stressed.	1.39	1.99
26.	Pupils should above all get the right answer when solving tasks.	2.89	3.35
29.	A pupil need not necessarily understand each reasoning and procedure.	3.15	2.80
31.	As often as possible such routine tasks should be solved where the use of the known procedure will surely lead to the result.	3.59	3.17
34.	Above all mathematical knowledge, such as facts and results, should be taught.	1.88	3.14
41.	When correcting classwork, above all the end results of the test tasks should be taken into account.	3.85	4.04
43.	In assessment (classroom performance), above all the presented solutions of the tasks should be taken into account.	2.44	2.91

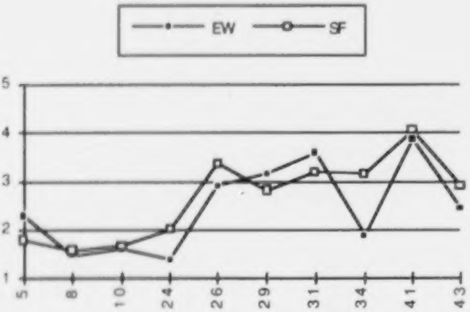

Fig. 1. The traditional perception (EW = Estonia, FIN = Finland).

The general conception of the traditional perception of mathematics seems to be rather similar in both countries. But schematic practicing (items 5, 29, 31) seems to be more important to the Finns than to the Estonians. Whereas the Estonian teachers clearly emphasize more delivering of mathematical knowledge (item 34) than their Finnish collegues do, and furthermore, learning and applying of computing techniques (items 24, 26, 43). In summarizing, the Finns pay more attention to routine practice, and the Estonians to mathematical content.

The formalist perception. There are 10 statements in the formalist perception of mathematics:

		EW	FIN
1.	In teaching, one has to deal in particular with (formal) structural mathematics, such as set theory, groups, ...	3.59	4.28
4.	One has to pay attention to the exact use of language (e.g. one should distinguish between an angle and the magnitude of an angle, between a decimal number and a decimal notation)	1.48	2.20
7.	Working with exact proof forms an essential objective of mathematics teaching.	2.61	3.80
11.	The proof of the Pythagorean theorem has to be worked in a mathematics lesson.	1.81	3.09
12.	The irrationality of the number $\sqrt{2}$ has to be proved.	3.42	4.16
13.	The universality of the formula $(a+b)(a-b) = a^2 - b^2$ has to be proved.	1.97	2.13
17.	In particular, the use of mathematical symbols should be practised.	2.08	3.24
19.	In teaching, one should procede systematically above all.	1.30	1.97
33.	Abstraction practice should be stressed in mathematics.	2.40	2.94
35.	During lessons, logical procedures should be emphasized.	1.42	1.69

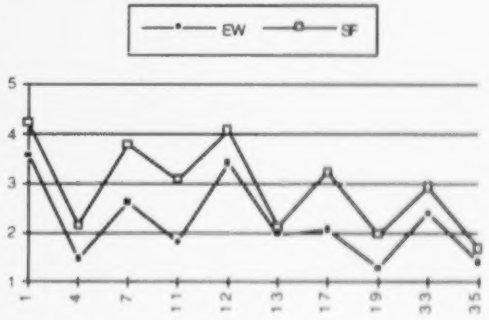

Fig. 2. The formalist perception (EW = Estonia, FIN = Finland).

Here, one may clearly see the difference between the Estonian and the Finnish teachers: The Estonians agree systematically more than the Finns with the statements. We could also say that the Estonian teachers have a more formalistic view of mathematics than their Finnish colleagues.

The constructivist perception. There are 15 statements which belong to the constructivist perception of mathematics:

		EW	FIN
2.	In teaching, intuitive working should be stressed.	2.21	2.44
6.	Mathematics has to be taught as an open system which will develop via hypotheses and cul-de-sacs.	2.67	2.60
9.	Teaching should be realized as project-oriented (beyond subject limits), and prerequisites for it should be created. (An example of a project: to buy and maintain an aquarium.)	2.79	2.62
14.	In mathematics teaching, learning games should be used.	2.27	2.33
16.	As often as possible, pupils should work using concrete materials (e.g. cardboard models.	1.32	2.34
18.	Social learning (e.g. working in groups) should be promoted.	2.41	1.95
20.	Pupils should experience that the same result one may reach in different ways.	1.25	1.36
28.	Above all the teacher should try to get involved in an intensive teaching discussion.	2.42	2.16
36.	In mathematics, group work should be used as often as possible.	2.72	3.00
38.	Pupils should develop as many different ways as possible of finding solutions, and in teaching they should be discussed.	1.58	2.05
40.	Pupils should have an opportunity themselves to formulate tasks and questions, and then to solve them.	1.79	1.67
42.	When checking classwork, above all different ways of solving tasks should be taken into account.	1.45	1.58
44.	In evaluation (class performance), above all the presented suggestions for solution should be taken into account.	1.76	2.06
45.	Pupils should have an opportunity (as often as possible) to independently develop their mathematical understanding and knowledge.	1.40	1.62
47.	As often as possible, the teacher should deal with tasks in which pupils have to think first and for which it is not enough to merely use calculation procedures.	1.44	1.57

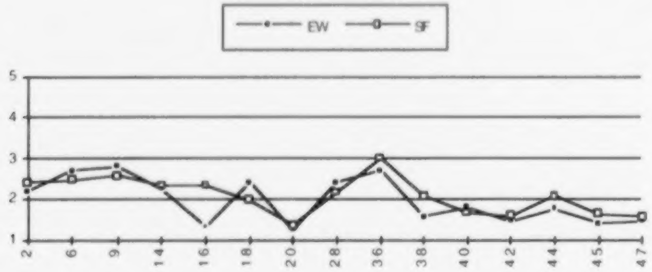

Fig. 3. The constructivist perception (EW = Estonia, FIN = Finland).

Here the conceptions of the Estonian and Finnish teachers are almost the same. The greatest difference is in item 16: The Estonians more clearly favor the use of concrete materials than the Finns. The teachers from both countries prefer the constructivist teaching style, the means in almost all statements being under 2.5.

Discussion.

The reliability of the results was estimated with the test-halfing method. The final report (Lepmann & Pehkonen 1993) will be published within a year, probably in the research report series of the Department of Teacher Education at the University of Helsinki.

An overview of Figures 1–3 gives some clear perspectives. The conceptions of the Estonian and Finnish teachers differ clearly from each other in the formalist perception of mathematics: The Estonians agree more than the Finns with the formalist aspects of mathematics teaching. Whereas in the two other perceptions of mathematics, there are no essential differences that can be observed.

The emphasis on the formalist teaching style of the Estonian teachers has two apparent reasons: (1) The unified and official mathematics program for the whole Sowjetunion, in which the use of deductive or axiomatic methods began already in grade 6. (2) The oral mathematics examinations which are used in high schools and for university entrance.

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Mental maps in geographical research and teaching

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A free-hand, map-like sketch drawn on one plane shows the individual's subjective conception of the environment, of an area or a phenomenon. Mental maps apply both to the research as well as to the teachers who want to study their pupils geographical world view.

A framework for research

Geography as a spatial science spans a very different range of spaces, from the objective mathematical space to the subjective experimental space full of human meaning, personal experiences and collective memories (see the article "The idea of space in geo-graphy"). The main framework for research in behavioral geogra-phy focuses on environmental cognition. The rationale for looking at cognition is a simple one (Whamsley et al. 1984, 8): *"If we can understand how human minds process information from external environments and if we can determine what they process and use, then we can investigate how and why choices concerning those environments are made."*

This, however, is not an easy task, partly because of an ever-present feeling that how we interpret the environment and how we behave are obvious (Downs et al. 1977). As a result, it is a major achievement to analyze processes often taken for granted and to come up with answers to questions, such as how we learn about the environment and how this learning influences our everyday lives.

No agreement has been reached on the question of how a person observes and perceives the space around himself and how this information is stored. One conceptual framework that describes the *"how"* and the *"what"* of environmental cognition has been provided by Peter Gold (1980, 42). This framework proposes that information from the environment is filtered as a result of personality, cultural and cognitive variables to form two sorts of cognitive representation: *"images,"* pictures of an object that can be called to mind through the imagination, and *"schemata"* the frameworks within which environmental information derived from experience is organized.

The distinction between images and schemata is important and useful, although many writers have overlooked it and talked generally only about*"cognitive mapping"* to encompass those processes which enable people to acquire, code, store, recall and manipulate information in their spatial environment (Golledge 1987, 143). Environmental psychologists like Ittelsson (1978), Altman (1992), Horelli (1982) and Korpela (1992) associate not only perception and cognition with environmental experience, but also the meaning of environment and how it influences an individual. In any case, the individual is never passive in his relationship with his environment but is an active participant, giving meanings to concepts. Conceptually, this is fine, however, it is extremely difficult to prove or disprove this. In fact, one of the problems with the behavioral approach in geography is that conceptual thinking has developed ahead faster than the testing of such thinking (Walmsley et al. 1984, 9).

Cognitive or mental maps

The cognitive map is an organized representation of spatial environment in the human mind (Downs et al. 1977, 6). The use of the word *"map"*, together with the terms *"cognitive"* or *"mental'"*, is in a way misleading because representation is not generally thought to be an analogy of the geographical map-concept. The metaphor *"a map in the head"* has been used and discussed mainly by cognitive psychologists (Kuipers 1982, Kolers 1983, Korpela 1985). Kuipers (1982, 202) claims that for spatial relations there should be a whole atlas in our heads, with a system of coordinates and a scale on every page. *"In fact, the atlas model is not sufficient, either; it is the data processing models based on associative connections that would best describe the nature of a cognitive map at a particular moment* " (Korpela 1985, 5).

In any case, cognitive maps of our minds function as a kind of navigation system when we move in our everyday environments or symbolically in larger environments. Neisser (1982, 94) uses a scheme of direction as a synonym for a cognitive map. With this he wants to emphasize that this is an active, information-seeking structure. Like the other schemes, cognitive maps also gather information and direct action. In a way it is a temporal cross section of the world, such as one believes it to be (Downs et al. 1973).

If needed, it is possible to differenciate between a cognitive map and a mental map conceptually. The cognitive map is a hypothetical structure in a person's mind while the mental map usually refers to concrete sketch maps, drawn by test subjects. At its simplest, a mental map is a free-hand, map-like sketch drawn in one plane that shows the individual's subjective conception of the environment, of an area or a phenomenon (Rikkinen 1989, 146). It refers to a research technique which has been much used when studying people's geographical world view (e.g. Saarinen 1973, 1987; Takala 1982; Chiodo 1993; Hayes 1993; Mikkola 1993). Defined this, a mental map has largely the same content as a traditional map. Humanist geographer Tuan (1975, 205) defines a mental map as a special mental image which is loosely related to knowledge obtained through senses, but which offers a spatial imaginary world.

Development of cognitive mapping

There are three very different views among researchers on the development of children's spatial cognition. *"Nativists"* think that a child is given an innate ability to organize his environment. *"Empiricists"*, on the other hand, emphasize that it is the external reality that determines and regulates the development. Between these two opposite perspectives is *"constructivism"*, which sees spatial ability as constructed out of some sort of interaction between inherited and experiential factors. The development of the skills needed in organizing the environment is connected with the age of an individual and his level of thinking (Matthews 1992, 69).

Piaget has developed his own system theory on the development of children's spatial cognition (Boardman1983; Rikkinen 1989). According to geographical studies, Piaget underestimated children's spatial ability. However, the development of cognitive mapping can be observed with the help of mental maps representing the way to school or the immediate surroundings. On the basis of his studies, Simon Catling (1978; Rikkinen 1989, 63) has worked out a standard map series. Comparing the maps of his own students with this series, a Finnish teacher may also determine students' level of thinking. In this same context, Catling also emhasizes that without systematical teaching, an individual will never reach full ability to read a symbolic map.

When interpreting mental maps, it should always be kept in mind that the map drawn on paper is not necessarily identical with the individual's internal image. The lack of motivation and the mo–toric skills needed in drawing, as well as the inability to express knowledge in a symbolic form, may considerably lower the quality of mental maps and give the wrong picture of the mapmaker's spatial abilities (Matthews 1986, 126).

Mental map in teaching and as a research instrument

In geography teaching, mental maps, representing areas of different sizes, can be used to evaluate the amount and quality of the geographical knowledge of both individuals and the class as a whole. The use and significance of the technique depends on the fact of whether it is used before or after the teaching itself. Used as a pretest it will help the teacher to direct his teaching. As a posttest, it gives feedback on the effectiveness of the instruction. Characteristic of geography, mental maps provide an alternative to conventional tests.

The drawing of a mental map can be a creative learning situation when the student himself realizes how geographical areas and places are connected with each other, forming an organized conception of the world (Hart 1981, 228). The student has an opportunity to follow the progress that is going on in his own geographical world view.

Because of the amount of both subjective and objective information condensed on mental maps, they provide a rich resource for research. The basic assumption of the research using the mental map technique is that the individual tries, on the basis of his mental image to draw a map that is as good as possible. However, it is more like the creation of an artist than the construction of a scientist.

But the mental map technique as a research method has its own problems. Among these are, e.g., difficulties in interpretation and subjectivity, which easily make separate studies incomparable, as well as problems in converting the data into a quantitative form. After all, this can be considered an efficient and simple research method, providing not only a wealth of information but also a psychological insight into the world of a mapmaker. Besides, in international use, the problems of lingual expression and translation can be avoided (Saarinen 1987). For research using mental maps, a holistic perspective is more important than the accurate measurement of distances or relative sizes of areas.

In Finland, the mental map technique has been used a lot in theses both in geographical and teacher education. In the Department of Teacher Education at the University of Helsinki the research project *"The environment of primary school children"* , led by Hannele Rikkinen, Associate Professor (1992), investigates 7-12–year–old school children´s views on the spatial elements in the geographical world as well as their local identity. This study is based on the idea that a human being is spatially definable in many ways and on many spatial levels, from his own everyday envi–ronment to the national, continental and global level. In the course of maturation and learning, awareness should increase on all these levels in students' minds as a part of their geographical world view. This study pursues the knowledge of how this awareness develops and which factors affect it. The focus is on the physical environment, where nature and man-made objects are not separated, and the social environment is included only as far as it is brought into the focus by researchers in research situations.

Good examples of the project are for example the theses of Leena Mikkola and Katja Pietilä. Mikkola examined the development taking place in the mental world maps of sixth graders in comprehensive school within a year. The aim of Katja Pietilä's study was to find out how primary school children's conceptions of the familiar environment develop as children grow up and, also, if there are any differences between boys and girls.

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Teaching the force concept for engineering students. A constructivist approach

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A research project to evaluate and promote the learning of the force concept in engineering education is reported. The project has four stages: Firstly, we tested engineering students' ideas about the force concept before physics lectures and after "normal" lectures. Secondly, we analysed the results of the tests and the Newtonian force concept itself. Thirdly, we restructured the physics course on the basis of the information gathered in the first two phases. The last stage is to analyse and report the results of the teaching experiment. In this paper the background and the realisation of the course is reported. Also, some initial results of the experiment are given.

Theoretical ideas for the study

The logical positivists of the Vienna Circle claimed that science starts from pure observations and hard facts. The modern view is that scientific inquiry never starts from facts and observations alone. Observations are interpretations of phenomena, depending upon the acceptance of a particular theory. Thus, theories are prior to experiments and all "facts" are theory-laden. We can interpret phenomena only in terms of the existing knowledge, and at the same time our ideas about the external world are in constant change.

The shift in the philosophy of science from empirical positivism to modern views is reflected in pedagogy as the shift from behaviorism to constructivism. In the behaviorist tradition, researchers were only interested in "pure" observations and not in the inner mental models behind the overt behaviour. On the contrary, in the constructivistic paradigm we suppose some kind of mental models with which we try to explain learning.

From the literature we can find many constructions of constructivism. For the purpose of this article, constructivism will be defined trough the following two principles (Duit 1993):

- the trivial constructivist principle: Knowledge is not passively received but actively built up by the cognizing subject, and
- the radical constructivist principle: The function of the brain is adaptive and serves the organisation of the experiential world, not the discovery of ontological reality.

We must clearly separate the epistemological and ontological aspects of constructivism. Constructivism can be regarded basically as an epistemological doctrine. It is against naive epistemological realism, but it is in accordance with critical realism. Constructivism is also in accordance with ontological realism. We need not consider solipsism or any other kinds of ontological idealism.

A pedagogical research project may be characterised as constructivistic if the researcher adapts the mentioned constructivistic principles. Basically, this means that the researcher should construct her/his constructivistic learning model. The researcher plans the research according to the constructivistic principles and interprets the results with them.

When we study students' understanding, we may observe constructivism in at least three layers: students construct their knowledge about the empirical and theoretical (e.g. Newtonian mechanics) world, teachers construct their knowledge about the world including the students and their ideas, and finally the researcher constructs her/his knowledge about teachers and students. In the project reported in this paper, the teacher and the researcher are the same person.

Background for a new mechanics course

If we base our instruction on the constructivist theory of learning, we have to take the students' initial ideas seriously. When we planning a new course in mechanics, we should take into consideration the students' preconceptions of the force concept and also the analysis of the force concept in classical mechanics.

By following this advice, I tested engineering students' understanding of the force concept. The main results of the tests are: Students have the impetus conception of motion and they use the dominance principle in interactions (Viiri 1993a, 1993b, 1993c). The results are in accordance with the tests made by other researchers in other countries.

The analysis of the Newtonian force concept (Viiri 1992) revealed two ideas which are contrary both to the students' ideas, and the pre-

Newtonian theory of motion. In Newtonian physics force is a relational concept which results from interaction between bodies. Also, the Newtonian idea that force is the reason for the changes of momentum is contrary to the students' ideas.

Since it has been shown in our tests and in numerous other tests world-wide that students do not change their initial "naive theories" by standard teaching, we have to change our teaching. Because of the empirical and theoretical results of our research, the new course should be based on the concepts of interaction and momentum.

Other researchers have drawn the same kinds of conclusions. One of the results of the force concept inventory made by Hestenes et al. (1992) was that we as teachers should concentrate on the impetus and dominance ideas. If students overcome these two preconceptions they will also understand the other ideas of Newtonian mechanics.

Because students have the impetus conception, and it is almost like the momentum concept in physics, it might be worth while to start the mechanics course with a special concentration on the momentum concept. For instance, Schollum et al. (1981) and Thijs (1992) have reported teaching experiments starting from the momentum concept.

To overcome the dominance conception, it might be valuable to concentrate on the interaction idea. Maloney (1990) underlines the importance of the interaction idea in teaching. In his opinion "if we want students to really understand the physicist's concept of force, then we must help them realise that all forces are interactions that always involve both an agent and an object."

The new course to teach the force concept

During the autumn semester 1993 I tried to adopt the results of the tests and the analysis of the Newtonian force concept to the teaching of the force concept.

The structure of the course was: some basic kinematics (rectilinear and curvilinear motion), momentum, interaction and force. Because of the poor experimental equipment, we had no demonstrations or experiments during the lessons. We only used lectures with discussions and mathematical exercises. We used no student-centered methods because we wanted to change the course only minimally so that we could analyse the effect of the new structure of the course. Because the teaching experiment was carried out during a normal physics course with no extra time, we had only about 30 hours in total.

The basic idea of the course was that the students should learn that the interaction between bodies is the reason for changes in motion. We investigated various situations where the body's momentum changed and the students had to identify the interactions and the forces. Students had to mark all the forces and name the forces, such as $F_{\text{table on the book}}$. The reason for this special way of marking the forces was that the students should understand that there is not a single force and that every force has two parts: one body acts on another body and vice versa. If the students drew the vectors for "the forces of the motion", they had to be able to answer which body is the other part of the interaction. After noticing that there was no other part, they should conclude that there were no "forces of motion".

Results of the teaching experiment

The students' understanding of the force concept was tested in five technical institutes: in our own institute after mechanics lectures, in two other institutes before and in two institutes after mechanics lectures. We did not use the pre-test in our test group because the tests we made earlier had shown that the students were very interested in the questions and the test might influence their learning. The force-concept test was adopted from Hestenes et al. (1992). We have not yet analysed the results and they will be reported in another study.

Discussions with the students during the course revealed some initial results. The Newtonian force concept seems to be very hard to construct, whatever the teaching method. Therefore, the results seem to be bad if it was thought that the new course would be very effective. One reason for the not so excellent results might be that the engineering students in technical institutes have already studied mechanics in secondary school and in vocational or high school. They have constructed their own ideas and used them for years. A course of only a few weeks is not enough to change their ideas. The positive point of these "bad" results is that they support the constructivistic model of learning: Students have constructed their models and they do not change their own models very easily.

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PART III: ACTION RESEARCH AT SCHOOLS

How to use students' comments in the planning of chemistry lessons?

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Introduction

Generally students in senior high school think that chemistry is too theoretical, too dry and too difficult. It is very useful to consider student opinions and experiences in the planning of high school chemistry lessons. The students experiences can be collected by interviewing them, by letting them write essays, by using questionnairies, - or by using combinations of these methods. Students' opinions can be collected at the beginning of a course, after some special occasion (experiment, project, visit etc.) or at the end of a course.

Experiences

During the last two years I have collected students opinions about teaching by using all the above mentioned methods. I became familiar with the use of questionnaire when I was studying chemistry in Canada at university level during 1988-1991. They were used at end of every course.

If a questionnaire is used, it is important to pay attention to the form of the questions. They can be in essay form, multiple choice or both. In order to obtain the best results, enough answering time should be reserved. A good alternative is to let the students answer the questions at home. I got more answers when they had enough time. Questionnairies with or without names may be used. Usually students like to answer the questionnairies without giving their name.

I started to collect my students' opinions by using a free interview (students in small groups) at the beginning of a course. But it was generally not very successful. The students were too shy to give their opinions even they were discussing in their groups. Answers like: " the teacher shoud know what to teach and how to teach" , were typical. Free essaytype questions (e.g. In what way would you like to study chemistry?) at the beginning of the course did not give much more. The students usually answered very briefly.

After varying experiences using different methods, I nowadays prefer to collect the information through a questionnaire that contains both multiple choice questions and essaytype questions. For example, in the beginning of the first senior high school chemistry course I usually let my students fill in a questionnaire concerning their experiences and background in their previous chemistry studies. In this questionnaire they are allowed to give their opinions about the topics of the course, about teaching methods, project plans, visits and marking.

After administering the questionnaire I read their answers as soon as possible. I plan the contents of the course taking into account their opinions as much as possible.

Sometimes I put together statistics. For example, if I had asked about project plan such as: Would they like to visit one of the chemical industries close to our school? If most of the students liked the idea, I would carry it out. They would be told about the results of the questionnaire during their next chemistry lesson.

I have used a questionnaire to collect information about some experiments conducted. For example, I wanted to know the students' opinions about the use of microscale equipment which is a much smaller than conventional scale equipment. Small plastic equipment is inexpensive, making it possible to use with large groups (35-40 students). Also it is advantageous to use outside the normal class room for example in auditoriums. In my case, due to the lack of room space, it is the only possibility to do experimental chemistry. I also think that by condveting experiments, students learn chemistry.

For example I studied the use of the microscale method, through questionnaire below, with students (36 students) who had determined the amount of citric acid in orange and grapefruit by a normal titration and by using microscale equipment. The students were asked, for example,

- how they liked the small microscale equipment (polyethylene plastic pipets and polystyrene cell wells) and
- which problems and advantages they encounterd in using this equipment compared to the traditional titrations by using a byrette.

The results encouraged the use of microscale equipment in the near future. Mostly, students liked it because it required much less equipment cleaning. Also, the result of titration was as accurate as using macroscale equipment (a buret). Futhermore the work involved the use of a smaller amount of chemicals, resulting in it being safer.

Questionnaire

You have just carried out an experiment by using both "microscale" and "macroscale " equipment.

1. I am a boy ______ , a girl _______
2. What good points do you see in the use of microscale equipment?
3. What is the most difficult/inconvenient part of the use of microscale equipment?
4. Estimate the validity of the results (select one choice):
    a) microscale equipment
    ___ good ____ not accurate _____ something else
    b) macroscale equipment
    ___ good ____ not accurate _____ something else
5. Which method would you prefer in similar experiments?
    ____ microscale method _____ macroscale method
    Arguments:

Conclusion

It has been very useful to obtain students' feedback, especially at the end of a course. They have estimated the uses of different teaching methods, the good and bad sides of the teaching. In addition, they have pointed out things that the teacher should take into account. The students' attitudes towards the questionaires have been positive, if not used too often. The answers reveallation that they appreciate being taken into consider in the planning of the teaching.

The students' feedback has been very fruitful and useful in the development of teaching.

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Learning chemistry through active experiences - a case study on the primary level

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The main purpose of this study was to find out, if it is as easy to stimulate the natural curiosity of boys and girls towards chemistry through active experiences using problem solving technique. The teacher tried to find out the notable differences in their former knowledge and attitudes towards chemistry problems. By letting all children be "scientists" and creating an enthusiastic atmosphere in the classroom for meaningful experiential science by giving simple problems for children to solve the teacher tried to stress motivation and the development of positive attitudes. No notable differences concerning former knowledge were found. Both boys and girls were very well-motivated to solve the scientific problems and the atmosphere in the classroom was very good. All children discussed the results in groups, and constructed the meanings of what they heard or observed by generating links between their existing knowledge and the new phenomena.

Introduction

Learning is an active process. In this process the learner is active and is building up his own knowledge. The function of the teacher is to stimulate the learner to recall concepts and to help him to construct solutions to problems, not to teach answers to questions (Marjoribanks 1991). Learning outcomes depend not only on the learning environment, but on learners' former knowledge. Experiential learning involves the whole person, both cognitively and affectively. Children's conceptions, purposes and motivations influence the way they interact. "Learning by doing" was Dewey's main idea (1915).

"Meaningful science" is a term used with many connotations. Meaningful learning underlies the constructive integration of thinking, feeling and acting. It involves the learner's conscious effort to relate new knowledge to relevant existing concepts or propositions in his cognitive structure, and leads to the progressive differentiation of cognitive structure.Integrative reconciliation of new meanings with old meanings may correct misconceptions (Novak 1989).

Research problems, methods and description of the classroom setting

The purpose of this study was to find out, whether there are any notable differences between 9 to 12 years old boys and girls, when we think about their former knowledge and attitudes towards simple everyday chemistry problems. Another purpose was to study if it is as easy to activate boys as girls through active experiences using problem- solving technique.

This study was carried out in two primary schools: Jylhä and Luonetjärvi during the 1993 spring term. Group sizes from 10 to 13 children were used at a time (N= 36). Children between the ages of 9 and 12 years were motivated to participate in laboratory activity by being given small research problems to solve. They worked in pairs and each pair was asked to discuss the results with other pairs before making decisions and writing down the results.

In the beginning of each part of the laboratory activity, the teacher evaluated the former knowledge of the children by asking them questions concerning the concepts to be learned. For example, regarding the acid-base-concept, children were asked: When you hear the word 'acidic', what does it bring to your mind?" The teacher explained the concepts in question at the beginning of the working sessions, tying them to the childrens' former knowledge and everyday life by some examples. During the working session the teacher and the student teacher evaluated the children all the time by taking notes and using video-taping.

The teacher tried to create a physically and emotionally safe environment so as to encourage emotional investment. During the laboratory session children were taught the main principles of problem-solving method and given different types of problems. The research problems presented for the children were following type:

1) Is black color just black? 2) Is it possible for you to arrange different materials that you can find in your kitchen in such an order that you can tell which one is the most acidic or the most basic by using red cabbage juice?

An example of experiments : Is the colour black just black?

The purpose of this task was to teach children certain concepts and to help them to see that chemistry is just "a bunch of simple things"; though chemists use such difficult words that it is impossible for young children to understand. Children's former knowledge was first investigated by raising some questions concerning a colourmap. They were given concepts, such as: compound, solution, solvent, solubility, mixture, molecules (small parts) and chromatography. The teacher explained every new concept using different connections to the every day life. After giving general information, the teacher gave children the tools to create their own research plan to solve the problem. She delivered instructions on how to set up their investigation. Children were encouraged to write down the hypothesis first, and then all the results and observations. The teacher helped them do this by giving them sheets which included questions concerning the research problem. Children were actively making suppositions, checking them and changing their ideas. When they had finished this part, they were encouraged to raise more research problems and construct their own investigations.

Results and discussion

Much of the new thinking about the teaching of science in primary schools is based on the notion that the first stage in learning is an active experience (Solomon 1986). The theory of learning-by-doing has always been used in chemistry, but usually only in connection with higher studies. In the past few years it has been realized that in order to get children more motivated in science, and to avoid many misconceptions formed during several years, we must begin to teach science starting on the kindergarten level.

In this study, no notable differences were found between boys and girls when attitudes or former knowledge were concerned, though girls in many cases had a better former knowledge regarding experiments used. No meaningful differences were also found between children of 9 and 12 years. Both boys and girls seemed to be equally well motivated in problem solving-tasks and as eager to discuss their results with the other children. Even boys and girls worked in own groups they were constantly changing results and ideas with the other groups.

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Constructive perception of figures through business logo designs

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The subject of this study is the perception of geometric figures through a gradual process, whereby the student learns to see how a figure has come about. The principal aim is to encourage the student to use verbal geometric expressions even without a set pattern. For this purpose, the student learns to give drawing instructions, both orally and in writing, which develops in him/her an understanding of the significance of geometric terminology.

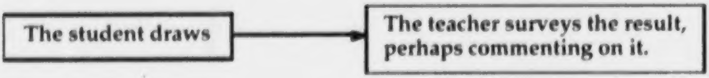
The aim is to stimulate the student's figure perception and to make him draw enlargements of them without the actual measuring or theoretical study of proportions. In addition, the aim is to encourage the student to describe what he sees, first orally and then in writing, and thus create in his mind the need to find names for shapes and figures.

Description of the task

Steps 1, 2, and 3 suit grade 7 well, and steps 4, 5, and 6 may be applied after the student has acquired some experience.

Step 1: Drawing

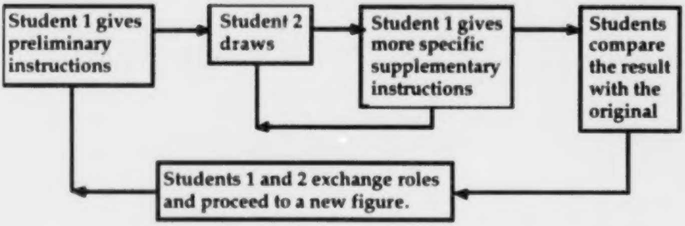
"You have been given a figure. Draw an enlargement of it." The figure may be quite demanding even for 7th-graders. Blank paper preferred to cross-ruled paper.



Step 2: Oral presentation

"You have been given a figure. Do not show it to your partner, but in-

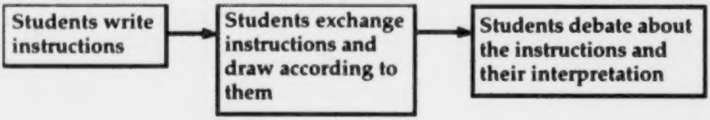
struct him/her how to draw an enlargement of it."
At this stage, the figure should be very clear. The student now has the opportunity to follow how well his/her instructions work throughout the process.


Student 1 gives preliminary instructions
Student 2 draws
Student 1 gives more specific supplementary instructions
Students compare the result with the original
Students 1 and 2 exchange roles and proceed to a new figure.

Step 3: Written presentation

"You have been given a figure. Do not show it to the others. Write instructions as to how to draw it on a separate sheet.
Then exchange instructions (but not the logos) with another student. Study the instructions written by your partner and carefully draw the corresponding figure on the instruction sheet. At this point, you are not supposed to ask your partner for further advice, but strictly follow the instructions."

After the figure has been completed on the instruction sheet, the original may also be glued onto it. As the students now compare their drawings, a spontaneous discussion on geometric ideas is bound to follow, with the teacher taking on to the role of an observer.


Students write instructions
Students exchange instructions and draw according to them
Students debate about the instructions and their interpretation

Step 4: Surveying a figure	"This is a business logo. What does it represent? What kind of enterprise could it stand for? Do you believe it will catch the reader's eye in the paper? Is the figure easy to remember?"
Step 5: Mathematical eye	"This is a business logo. What mathematical points do you notice in the figure? Could you calculate some things from this figure? Think up some mathematical problems based on the figure and solve them."
Step 6: Creating new	"Design a business logo for a particular factory, shop, etc. Use as simple basic geometrical figures as possible."

Conclusion

The chief aim of the above process was to approach the subject through perception, by first activating the right cerebral hemisphere. The student sees the figure and draws an occular enlargement of it without mathematical calculations. The next step is to activate the left cerebral hemisphere, the centre of verbal expression. The effect can be heightened by letting the student colour the figure he has drawn as he/she visualizes it. This reinforces the student's motor coordination, and the end result gives him/her aesthetic pleasure.

Time allotment. Steps 1, 2 and 3 each take one teaching period (lesson), which do not necessarily have to be in succession. Step 1 leaves some students enough time to draw more than one logo. Step 2 develops the student's verbal expression as he/she gets instant feedback on the accuracy of his/her instructions. Step 3 calls for a complete written instruction without gradual feedback. From step 4 on, it is not necessary to define the time span, since the process in the later stages is so creative that it involves the subconscious as well. Thus, steps 5 and 6 may best suit the senior high school level.

Description of logos:
Step 1: Rautia hardware store chain (old emblem for iron)
Step 2: An architect's office
Step 3: TOP Company
Step 4: Ähtäri Animal Park (initial Ä + bear)
Step 5: Finnish Newspaper Publishers Association

Environmental project work at secondary level

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Teacher Training School II, University of Helsinki

Introduction

In environmental studies at school it is important to awaken the interest of young people in environmental issues and protection. They should be taught to observe the state of the environment and to understand environmental questions in regional and global pers-pectives. By means of environmental project work, it is possible to stimulate reflective thinking and to develop attitudes and values. Attitude is considered a concept composed of three elements; know-ledge, emotions and the readiness to act.

Local problem-solving is considered an essential part of the environmental education process, particularly for the motivation of the students and for the aquisition of basic skills and knowledge. In sci-ence education we have good possibilities to lead our students to-wards direct contact with the environment. The use of an experi-mental approach in data acquisition is very natura to the sciences. Only through their own experiences in practical studies and measu-rements can students understand and interpret the official data and public discussions on environmental problems.

Experimental research project

Students in the Teacher Training School II in Helsinki partici-pated in The Baltic Sea Project, which was an international coope-ration project concerning the environmental education in the Baltic coastal states. Biology, physics and chemistry were the core disciplines of the project, but there was also an intimate cooperation with other subjects.

Figures 1 and 2 present the project's plans for studies in biology, physics and chemistry for seventh graders (aged 13 to 14).

The main plan of the project had been decided on by teachers, but all the practical work was done by the students. The teachers' role was to support the work of the students and help them in the acquisi-tion of equipment

The objectives of the project, from the student's point of view, were to get experiences of the seashore, to awaken interest in envi-ronmental issues, to learn to make observations and follow up the state of the seawater, to learn new concepts through experimental research and develop the students' own activity and cooperational skills.

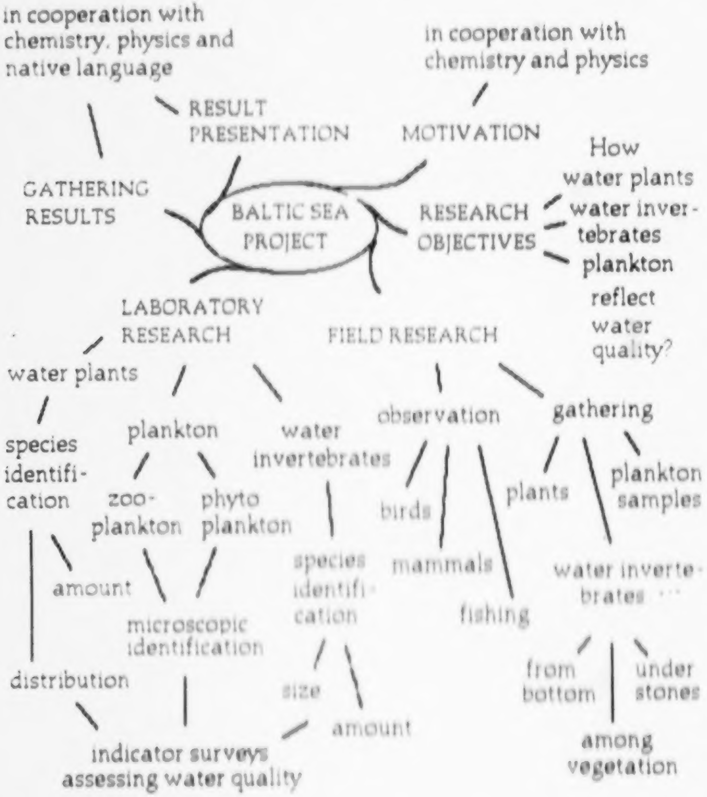
in cooperation with chemistry, physics and native language
in cooperation with chemistry and physics
RESULT PRESENTATION
MOTIVATION
GATHERING RESULTS
BALTIC SEA PROJECT
RESEARCH OBJECTIVES
How water plants water inver-tebrates plankton reflect water quality?
LABORATORY RESEARCH
FIELD RESEARCH
water plants
species identifi-cation
amount
distribution
plankton
zoo-plankton
phyto plankton
microscopic identification
water invertebrates
species identifi-cation
size
amount
indicator surveys assessing water quality
observation
birds
mammals
fishing
gathering
plants
plankton samples
water inverte-brates ...
from bottom
under stones
among vegetation

Fig. 1. The plan for studies in biology in the 7 th grade, during the Baltic Sea project

During the motivational phase each student spent about five minutes writing the answer to the question: What do you know about the sea around Helsinki? After writing their answers they shared their knowledge in group discussions. Many questions arose because the students had very different experiences of the sea.

During the first motivational field trip students formulated themselves their research objectives and the problems, which they wanted to study more thoroughly. They also selected and tested the research equipment.

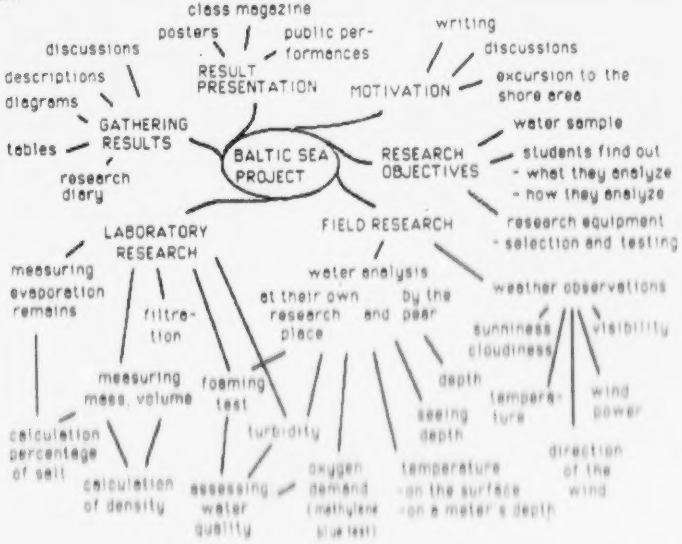
class magazine
posters
public performances
discussions
descriptions
diagrams
RESULT PRESENTATION
writing
discussions
MOTIVATION
excursion to the shore area
GATHERING RESULTS
tables
research diary
BALTIC SEA PROJECT
water sample
RESEARCH OBJECTIVES
students find out
- what they analyze
- how they analyze
research equipment
- selection and testing
LABORATORY RESEARCH
FIELD RESEARCH
measuring evaporation remains
filtration
water analysis
at their own research place
and
by the pear
weather observations
sunniness cloudiness
visibility
measuring mass, volume
foaming test
depth
temperature
wind power
turbidity
seeing depth
calculation percentage of salt
calculation of density
assessing water quality
oxygen demand (methylene blue test)
temperature
-on the surface
-on a meter's depth
direction of the wind

Fig. 2. The plan for studies in physics and chemistry in the 7 th grade, during the Baltic Sea project.

The research area was a one kilometer long coastline consisting of a rocky beach and a sandy beach where many water plants grew. Students visited the research area several times during the autumn. One trip to the shore took about 4 hours. During the field trips, all students analyzed weather conditions and the water quality by taking many kinds of tests and collecting materials, which were analyzed in the school laboratory during biology, physics and chemistry lessons. Students worked in pairs and the materials they collected were plants, water invertebrates, plankton and water samples.

One pair wanted to build a Baltic Sea aquarium and follow up how fish, water invertebrates, plankton and plants stay alive in an aquarium if you add no food and take nothing out. All the materials were collected from the research area and only a oxygenation pump was added. Students made observations of the aquarium du-ring the winter and it was marvellous to see that new life was born in the spring.

After the practical work students wrote reports of their studies in their mother-tongue classes. All these were published in the class magazine. Futhermore the students made posters to visualize their results.

The project continued in the 8th grade. They followed up the changes in the water quality by taking the same measurements as earlier. In addition, they made several kinds of chemical analyses to assess the water quality.

Evaluation

The project work and the accompanying working methods had a good influence on the social climate in the class, stimulating open-ness and initiative among the students. This was indicated by the students activity during the process. Project work also succeeded in a wakening the students' interest in environmental questions. They learned a great deal from the working process they were going through and got some knowledge of ecology. Also, many physical and chemical concepts were learned without difficulty during the project.

How do the secondary pupils understand the process of dissolving salt in water?

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An experienced teacher in collaboration with a researcher has studied how pupils apply the law of the conservation of mass in the dissolving process and how they describe the appearance of a salt-water solution. The effect of carrying out the study on pupils´ conceptions of the teacher´s ways of teaching is also discussed.

Introduction

According to the constructivist view, it is important that the teacher knows what and how her students are thinking of the phenomenon under discussion (Schollum and Osborne 1985). She has to take the students´ ideas into account both in planning and carrying out the activities in the classroom. When the teacher has had an old-fashioned subject education, in which the focus has been on the content with detailed facts, she has to change her methods of teaching profoundly. She may almost experience a crisis when she finds that the way she has been teaching leads to very little learning by the students. This report will deal with how an experienced teacher´s development towards a constructivist way of thinking started through her research work with her own pupils.

The main interest in the reseach work was how secondary school pupils describe what a salt water solution looks like, the words they use in the description and the level of explanation they give. The second interest is how well the pupils recognize the idea of conservation of matter in the dissolving process. According to Driver (1985), some secondary school students use the words "melt" and "dissolve" as synonymous, some think that, for example, sugar and water form some kind of compound, and some even denied the presence of sugar after dissolving. Some students think that sugar is still present in the solution, but it is lighter, some say that only the taste is left.

Research problems

It is known from previous research that very few pupils use the concepts of atoms and molecules in their reasoning in chemistry (Andersson 1984; Briggs and Holding 1986; Longden et al. 1991). Therefore, we also concentrated on finding out how the students would apply the idea of the conservation of matter which forms the basis for atomic theory and the concepts of atoms or molecules in describing the dissolving of salt in water. The second problem was based on the work by Novick and Nussbaum (1978) about the representation of air structure. The research problems were formulated as follows:

1) How do the pupils apply the law of the conservation of mass in the dissolving process?
2) How do the pupils describe what the salt-water solution looks like?

Method

The pupils were given a questionnaire which consisted of two questions. In the first one, the pupils had to estimate the weight of the salt-water solution when 50 g of salt was dissolved in 500 g of water. In the second question, the pupils were asked to draw, in a ready made setting, what the salt-water solution would look like if it could be seen. In both cases, the pupils were asked to give their reasoning. A total of 373 pupils (107 from the seventh, 150 from the eighth and 116 from the ninth grade) answered the questionnaire.

The mass of a salt-water solution. The fact that the idea of the conservation of mass is not clear to the students was proven again in this study. About 5% of the pupils applied the idea that wood and sand weigh more when wet than when dry "*The weight increases because the salt particles will absorb water in themselves*". Nearly 40% of the ninth graders thought that "*salt loses weight in water because it disappears completely*". Therefore, it seems important that more attention should be paid to this first quantitative law of chemistry, introduced by Lavoisier at the end of the eighteenth century.

Table 1. Distribution of the answers of the 7th to 9th graders by percentage, in the question about the mass of the salt-water solution.

	7th grade/107	8th grade/150	9th grade/116
more than 550 g	5	5	4
550 g	34	49	59
less than 550 g	60	44	37
500 g – 550 g	11	7	5
500 g	45	36	29
less than 500 g	4	1	3
no answer	1	3	0

What does the salt-water solution look like? The drawings of the pupils were categorized in five classes. It is interesting to notice that the distribution of the answers of the 7th and 9th graders are close to each other, while those of the 8th graders differ from them significantly in classes A and B.

Table 2. Distribution (in %) of the answers of the 7th to 9th graders in the second question, on the appearance of the salt-water solution.

	7th grade 107	8th grade 150	9th grade 116
A	16	28	20
B	34	24	29
C	33	28	30
D	16	16	20
E	1	4	1

A: clear solution, B: turbid, homogenuous distribution of salt, C: equal distribution of salt particles, D: Salt at the bottom, E: do not understand or salt on the surface.

The answers in class A were supported by reasonings like, "*You cannot see the salt*" but also, "*Salt changes into liquid*". The choices of class B were followed by such statements as, "*water becomes more turbid*", "*something is given off by salt which makes water greyish*". In a few cases, it was also said that "*salt spreads homogenuously all over*". In class C the role of particles and atoms or molecules was mentioned: "*dissolved salt atoms will float in water*", "*salt particles are equally distributed in water*". The seventh graders had been taught the concepts of atoms and molecules. In physics and chemistry they had also just been introduced to the ideas of the structure and behaviour of matter. They were eager to use these ideas. In the 8th grade, the pupils seem to be very confused. Therefore, they stressed the fact that "*the dissolved salt is not visible in sea water*".

Changes in the teacher´s behaviour in the classroom

Doing research on the subject of how students understand the phenomenon of dissolving, especially by looking at the students´ conceptions, changed the teacher´s practice in many ways. First of all, she no longer uses the ready – made work books, very much. The pupils have to decribe what they think and see in writing and by drawing. She is not trying to go through everything hurriedly: "*If I do not have time, I leave it*". The teacher and the class discuss more than before as "*simple things are not simple*". The pupils have to explain what they mean. They have to predict what they think might happen in an experiment and so on. But also, the pupils have started to ask more questions. The teacher´s work has increased, she has to prepare the lessons more carefully and also to gather more material and equipment for demonstrations and experimental work. The pupils like to do experiments, but it is hard to get them to think and wonder what the possible reasons are and how they could find them.

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Physics teachers' teamwork - taking into account the development of the pupils' ideas

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Introduction

All the lessons in our comprehensive school have been arranged into six-week periods, which means that physics and chemistry are studied during three periods in every grade of the secondary school. During one period the pupils have two double lessons a week for six weeks (a total of 24 lessons). This arrangement has provided the possibility to carry out larger entities of study, to discard unnecessary information and to concentrate on the most important concepts.

The aim of this article is to give an outline of the process in which the teaching was streamlined based on feedback from the pupils. In the first period of the seventh grade the subjects were the qualities and the behaviour of matter. The main concepts during the period were the states of matter, the concept of temperature and the changes in the state.

The concept of temperature and heat volume

The pupils' knowledge and ideas on the matter were charted in the beginning of the period, i.e. how they describe matter and what means they use to identify matter. The following step was to classify matter into three categories according to their state.

What has to be done to solid substance if you want to convert it to gas, or what has to be done if you want to convert a gaseous substance into a solid substance? Can all substances exist in all three states? Is there a difference if you melt two nails or two kilos of them? There was disagree-ment as to the right answers. During the conversation it became evident that pupils used the word "heat" irrespective of whether they meant the temperature or the heat energy.

A task was planned to clarify the difference between temperature and heat volume. The task of the five pupil groups was to measure the boiling point of water and the time before boiling had started. The test arrangement was as follows: the groups had beakers of the same size, but the amounts of water were 50 ml, 100 ml, 150 ml, 200 ml and 250 ml. Water was taken from a common container so that the initial temperature would be the same. Each group measured the room temperature to show the differences on the thermometers. The effect of the gas burner was discussed. A picture of the beaker and the amount of water in each group was drawn on the blackboard. When the water started boiling, the group marked the boiling temperature and time on the board.

It was found that the boiling temperature was independent of the amount of water; however, the greater the amount, the longer it took to boil. The pupils seemed to understand that time described the heat energy which transfers to the water. To check if the pupils had understood, we planned an inquiry for the following lesson with different substances and a different change in state.

During the inquiry, a couple of pupils asked how long the melting would take. In the answers the melting point was either half of the given or twice the given temperature. The study groups got the followingly correct answers : 3/17, 3/16 and 8/17. It was discovered that even though everything seemed to go fine, the pupils were not able to apply the information to another substance and to a different change of state. This experiment also showed that it is more useful to test the comprehension of the phenomena with the small inquiries described above than with traditional written tests, where the results to a great extent have correlated with rote learning.

The three states and the changes in the state

The boiling point of alcohol and the melting point of stearine were measured during the next lesson. It was found that substances have their own typical melting and boiling points. It was discussed whether any part of the substance could vaporize before its temperature had reached the boiling point. This was illustrated with the copper sulphate crystals that had gathered after water had evaporated from the solution. It was noted that evaporation had taken place in room temperature. This offered the possibility of defining the two concepts, evaporation and boiling, more accurately.

Then it was discussed if the vapour could be converted back in to a liquid state. The pupils suggested that the temperature be lowered. To illustrate the subject a distillation was carried out. Water coloured with food colouring was distilled. The first group used a colour solution which had been prepared beforehand; but as it seemed that the pupils had difficulties in understanding that the blend was a mixture of water and a solid substance, the other group started in another way. The colouring was dropped into the water in front of the pupils.

During the next lesson we wanted to test if the pupils could deduce the basic state of a substance if they knew its temperature. They used the table on melting and boiling points in the textbook as a guide. The pupils were asked the following questions:

1. A mercury thermometer does not work when the temperature is 40 degrees below zero. Why?
2. Why is an alcohol thermometer better when measuring low temperatures?
3. In what state is benzene when it is a) 0 °C b) 10 °C c) 100 °C?
4. What is the range of temperature variation when chlorine is in a liquid state?

Some pupils' answers to questions 1 and 2 were that mercury/ alcohol melted at -39 °C/-117 °C. Some pupils did not answer question 3 at all, or then they answered "Solid, liquid, liquid", or some other illogical order. Question 4 got the fewest correct answers. There was for example only one temperature given or the temperatures were given without the minus or plus signs. Based on the inquiry, one group checked once more what happened to a substance if its temperature was raised or lowered. The study was always begun from the state in which the matter in question was at room temperature, because pupils consider this "the normal state".

Learning the concept

The period was completed with two inquiries, the first of them is presented below.

Liisa puts a piece of zinc into an oven where the temperature is 1000 °C. She measures the temperature at one-minute intervals. She gets the readings 30 °C, 70 °C, 200 °C, 420 °C, 420 °C, 420 °C,...

1. Why does the thermometer give the reading 420 °C several times?
2. Liisa continues measuring the temperature. What will the readings be now? Will the temperature of zinc stay at 420 °C or will it reach the temperature of the oven, 1000 °C? Specify your answer.

"The piece of zinc takes on the same temperature as the oven." This was the answer of only 14 pupils out of 48. Most of the pupils stated that the temperature could not be higher than 420 °C. It seemed that some of them compared the situation with water, which was familiar to them. "Zinc has already vaporized at 420 °C." "Zinc vaporizes at 420 °C and the temperature of the vapour can get as high as 1000 °C." Many pupils had difficulties in understanding high temperatures. In the answers, for example, one of them was concerned about measuring the temperature and wondered if the equipment could hold out without breaking.

In a teachers' meeting it was noted that next year it would benefit the teaching to plan an experiment where, besides studying the melting process of a solid substance, the temperature rise of the liquid would also be examined. The test in which the pupils defined the boiling points of water and alcohol might have given them a misconception of a "terminal temperature" (a term used by a couple of pupils in the answers).

Conclusion

The teaching of new concepts was initiated by considering the pupils' previous knowledge and presumptions of the subject. The forming process of the concept was followed up by tests and it was reinforced with laboratory experiments where the pupil had to apply the new concept.

The teachers thought that analyzing pupils' results together was both fruitful and educating. They also got some information on how a pupil forms and works with a new concept. It was found that it is possible to reinforce pupils' concept development. The results from the inquiries led teachers to think about what the pupils had actually learned in the previous years.

Acknowledgement

This work has been done in collaboration with Maija Ahtee in her research project " Pupils' conceptions and the teaching of physics".

Development of secondary school students´ conceptions of energy using concept maps

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Helsinki

In this qualitative research study secondary students' conceptions of energy were studied, especially the development of their conceptions during the instruction of physics. A constructivist approach is presented in the research. The students' conceptions of energy were mapped before instruction and two times during the instructional period. The students were actively involved in constructing the concept of energy. The main method for collecting data was concept mapping.

Introduction

The concept of energy was selected as a studied concept for various reasons. Firstly, the concept is extremely essential for science and the modern society. The 'lifeworld' thinking (McCelland 1989) and scientific thinking are required of students, and in particular students should be able to change their modes of thinking in this respect. Secondly, the concept is taught as a physical substance in connection to several subsections of physics, e.g. mechanics, thermodynamics and electricity (Watts 1983). There is always a new and different approach to the concept, and so students have to construct the final, comprehensive and logical conception from these pieces of knowledge. Thirdly, energy is an abstract quantity which complicates the understanding of it. You cannot feel, store and consume an abstraction (Beynon 1990).

The purpose of the research

The purpose of the research was to find answers to the following main questions:

1. What kind of comprehension regarding the concept of energy was acquired by the students during the instruction of physics?

2. How was the concept of energy associated by the students to everyday life and how did it develop during the instruction?

Methods

In research of this kind data is usually collected through questionnaires and interviews. These direct and/or restrict the thinking of students. Therefore, to achieve valid results, a fundamental difference from the above in this research was to eliminate the external influence caused by the method on students' thinking. Consequently, concept map and essay were chosen to be used as the methods. Concept mapping was applied based on the theories presented by Novak and Gowin (1984) and Åhlberg (1990a, 1990b). The concepts were surrounded by a line and arrows with names, called links, linking concepts together.

This study encompassed two ninth-year classes (21 students) in one comprehensive school. Students produced two concept maps, the first before instruction and the second eight months later, and the essay four months after the first map.

Results and conclusions

Development of students' comprehension of the concept of energy during the instruction of physics. The body of knowledge about the concept of energy enhanced and improved during the instruction. The number of all concepts and links associated to energy increased 100-200%, especially meaningful concepts. Also the number of links per concept increased (Table 1). It is remarkable that the number of concepts having four and five links increased respectively 245% and 238%, respectively. In addition, the main concept, connected with the highest number of links, altered from 'lifeworld' concepts such as industry and household to scientific concepts such as heat energy and electrical energy. The conservation of energy appeared in most of the second maps (52%) and in the essays.

Consequently students' comprehension of the concept of energy changed as follows: More details, especially essential details, were associated with the concept of energy. So, the holistic view of concept of energy expanded and it's content became more meaningful, logical, consistent and coherent. Adopted knowledge accommodated the comprehension of energy, it became more hierarchically organized. Students will learn, for example, to classify concepts better, to distinguish super and sub-concepts and to understand causal relations within a concept. More scientific concepts began to be associated with the concept of energy. Thus students learnt better to understand the scientific content of the concept of energy.

Table1. Comparison of the first and the second maps. The numbers indicate the numbers of such meaningful concepts which are connected with other concepts by one, two, etc. links. The increase is calculated in percentages.

	1 link	2 links	3 links	4 links	5 or more links
First map	156	70	27	11	8
Second map	358	160	33	38	27
Increase %	129	129	22	245	238

The students' association of the concept of energy in reference to everyday life and how it developed during the instruction. All students had concepts of energy from everyday life on their maps. Many of them had even more on their second map than in the one made by the researcher. Comparing the first and second maps shows that 40% of the students had fewer concepts of everyday life on their second map than on their first. An increase was found in 60% of the maps. It is obvious that by constructing the conception of the content of energy in a more scientific way, some students could relate it more closely to the concepts of everyday life. Consequently, these students experienced their learning as more meaningful.

Although the number of concepts of everyday life was remarkable on some maps, the number of links on these maps was smaller compared to the benchmark map. So these students could not associate the everyday life concepts of energy logically and coherently with the scientific concepts of energy.

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Open investigation as a teaching method. A case study of teaching heat transfer

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Open investigations emphasize the constructivist point of view as pupils go through the process of the scientific method, applying their own thinking to the experimental and theoretical framework. The problems in open investigations are often found in everyday life and are therefore closer to the pupils than those containing pure physics items. The attitude of the pupils was generally positive, though the seventh graders were more active and keen on planning and working than the ninth graders. The study showed that open investigations should be started early, as older pupils are more restrained and oppose new methods.

Aims and participants

This report is based on a master's thesis (Lindroos 1993) for which the teaching researcher had to plan how to apply an open investigation method in teaching physics, and how to realize it in practice. One of the starting points for this approach was the findings of Tasker and Freyberg (1985): "When pupils are questioned about why they are doing what they are doing, what they have found out, the significance of a particular result and its relationship to previous findings, the experimental design of the activity, or the consensus scientific view of the concept behind the investigation, their responses frequently suggest major discrepancies between the teacher's intent for the lesson and the pupils' actual involvement".

The purpose of the study was to clarify what kind of preparations are needed in order to carry out open investigations in practice, how the students manage in different phases during the work and how they understand the concept of, for example, controlling variables. The behaviour of the pupils was observed, as the motivation of students to work on their own development and to apply their own knowledge and ideas, is one of the main aims in open investigations.

Two classes with 14 to 18 students, from the seventh and ninth grades (aged 14 to 16), took part in this study. All the students had the same physics teacher. The project was carried out in March, when the students in both grades were studying thermal phenomena. This area was chosen, as many of these phenomena were also familiar to the students from everyday life; and the equipment needed to perform measurements was fairly simple.

The teaching researcher planned and carried out the project in three double lessons over three successive weeks. The regular teacher was also present all the time and helped different groups when needed.

The work of the pupils in the other seventh grade group is reported here. The pupils chose the general problem "How is juice best kept cool at room temperature?" as their common task.

Focusing, choosing and defining the problem. At the beginning of the first double lesson the phases of the open investigation were shortly introduced to the pupils. At the same time, different items related to heat, such as thermal equilibrium and phase transitions, such as melting, were discussed superficialy. The different aspects to be considered in investigations were taken up in connection with appropriate examples. The problem, how to find all the variables, was especially practiced. The question of controlling varibles in fair tests was taken up just when the different groups had confined their own problem.

The pupils suggested about four items per pair as common problems. These were written on the blackboard, and by combining some of the suggestions, the final form was accepted. After that, the pupils continued to discuss in pairs, just what factors should be taken into account when juice is to be kept cold. The variables involved in the investigation were agreed to be the amount, concentration and initial temperature of juice, the material, form, insulation and initial temperature of the jug and the amount of ice. The effect of the independent variables on the warming up of the juice was then discussed, and the dependent variable was defined as the change of temperature in a certain time interval. The word "best" in the research problem was then defined to mean that "juice will stay cold best when it´s temperature rises less". The idea of fair-testing and controlling the variables was now taken up more precisely.

At the end of the first double lesson, the pupils formed five groups of 2 to 4 persons. Each group decided on which independent variable they wanted to concentrate. The bigger groups had to study the effect of two variables. The rest of the time, the groups planned how they could carry out the relevant measurements.

Exploratory, carrying out the measurements. The second double lesson was used to carry out the measurements. At the beginning of the session, the idea of fair-testing was recited. Also, the aspects which have to be taken into account in temperature measurements were discussed.

The research groups planned and accomplished the measurements fairly autonomously. The controlling of the initial temperature was found to cause difficulties. For example, one of the groups was puzzled with their results until they themselves noticed the variation in the initial temperatures of the different samples of the juice. They decided to repeat all the measurements to correct this mistake.

Reporting and presenting. The third double lesson was used to analyze and present the results. The focus, in presenting the results, should be such that the others would understand what had been done and what results had been obtained. In particular, the role of the tables and graphs were pointed out in presenting the measured values in making conclusions.

In the presentation, each research group told the others what they had studied, how they had carried out the measurements and what the effect was of the independent variable they had chosen in the warming up of the juice. The results were shown on an overhead projector. The other pupils had the possibility to offer their opinions and remarks on the subject. All the pupils were also invited to think of possible ways to improve and enlarge the present investigation.

Each research group was then asked to write a short report of the work they had done, so that all the reports could be combined together. They were instructed to write down the problem or what had been studied, the method used, the conclusions or what result had been obtained. The report should also include any interesting observations made during the work, and the possible deficiencies found after the measurements had been completed. The writing of the report turned out to be the most difficult part of the open investigation in all the groups. The pupils were not used to reporting their practical work in writing.

Remarks

Most of the seventh graders were interested and worked actively in each part of the open investigation. Some of the ninth graders worked keenly enough, but they seemed to lack the eagerness and tendency towards exploration which was shown by the seventh graders. Even inventing possible research problems was much harder for the ninth graders. They were more used to fairly strict guidance during their practical work, whereas the open investigation method demands a more autonomous attitude.

From the teacher´s point of view, it can be said that more time should have been used in carrying out the investigation. In particular, it seems important that pupils should be trained in various aspects, such as how to find the variables, how to understand fair-testing, and to construct tables and graphs (see e. g. Jones et al. 1992).

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Introducing polynomial functions with the aid of the graphic calculator

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Lower secondary school pupils explored graphs of simple polynomial functions of degrees 1 - 4 in a learning environment built around the graphic calculator. The exploration consisted of first graphing functions whose equations were given and then making hypotheses about the graphs of other related functions, checking the hypotheses with the calculator. It appears that the graphic calculator, which has mainly been considered a tool for the upper secondary school, can be used to great advantage in the lower secondary school too, especially in the introductory stage of concept formation.

Background

According to constructivist learning theory, pupils should be encouraged to actively construct new concepts and to explore their attributes and their scope in order to incorporate them effectively into their cognitive structures (Noddings 1990, 10). Teaching methods compatible with constructivism strive towards such learning. They focus on creating learning environments conducive to active concept construction.

Incorporating the new concept into the cognitive structure of the learner is facilitated by suitable learning arrangements in the introductory phase of concept formation. A useful model in this connexion is a learning paradigm developed by Haapasalo (1985) from that of Galperin, which incorporates five stages in the learning process (Fig. 1).

The function concept is one of the central mathematical concepts pupils should become familiar with in the lower secondary school (in Finland grades 7 - 9, ages 13 - 15). The availability of graphic calculators offers the pupils quite novel possibilities for experimenting in the introductory stage of concept learning, especially in connexion with such concepts as the function, in which the numeric, graphic and symbolic aspects are equally important. The possibility of producing a large number of graphs easily and quickly can give the pupils a new insight into the way the graph of a function is connected with its equation and with the numeric information incorporated in it. Graphic calculators can be used to create learning environments which incorporate pupil activities such as experimentation, suggesting and testing hypotheses, and finding general rules.

1. Concept formation
Orientation into the concept
Defining the concept

↓

2. Concept accommodation
Recognizing the concept
Producing the concept
Strengthening the concept

Fig. 1. Stages in concept learning

Investigating polynomial functions

For a few years now we have had recourse to a set of ten Casio fx-7000G graphic calculators for use mainly in the upper secondary school. In grade eight (pupils of age 14), the rudiments of the function concept, limited mainly to the study of linear functions, are taught. We began to wonder how graphic calculators could be used on the lower secondary level. Our eighth grade pupils first used them successfully to investigate linear functions and were also encouraged to experiment with graphs of their own (Paasonen 1993). As the pupils were very eager to continue using the graphic calculator, we decided to try to have them investigate simple polynomial functions of degree 1 - 4 in a more systematic manner.

The pupils, working in pairs, were given four-page worksheets. They were instructed to first graph the given functions and then make assumptions as to how a slight change in the equation, e.g. substituting

$y = x^2 - 3$ or $y = (x - 3)^2$ for $y = x^2$,

would affect the graph. After making a tentative sketch of their hypothesis, they were instructed to check it by graphing the function on the calculator. The pupils worked actively and enthusiastically, carrying on lively, even heated discussions, and were often right in their assumptions. When checking with the calculator showed their guess to have been incorrect, they tried to find the reason why things had not worked out as they had thought. Since the four groups involved (about 16 students each) were quite heterogenous, some pairs only completed the first page while several pairs completed the entire four-page worksheet and went on to graph functions of their own.

Having recourse to the graphic calculator enabled the pupils in the course of one lesson to enlarge their existing concept of a function, which had involved only linear functions in addition to some graphs of empirical functions. They also learned to make hypotheses about the relation between the equation and the graph of the function, and found that these relations are analogous to those they had discovered in connexion with the linear function. Non-linear functions were not dealt with in the following lessons, but when we included a problem on the graphs of these functions in a unit test some three weeks later, nearly all of the pupils who completed the entire test managed to solve the problem. It thus seems that even relatively little work in an environment featuring the graphic calculator as an aid can have a considerable effect on the cognitive structure of the learner.

Possibilities of the graphic calculator

It is quite evident that the graphic calculator offers great, even revolutionary possibilities for enriching the mathematics curriculum in the upper secondary school (e.g. Demena & Waits 1992, Hector 1992). Our own experience suggests that it can also be used in the lower secondary school to motivate the students and to bring new depth and breadth to the issues investigated. In creating learning environments in the constructivist sense, the graphic calculator offers unique and exciting possibilities.

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Project work – a way to learn actively

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Project work is one way to organize learning experiences so that pupils can learn actively and investigate real life phenomena as a whole, not cut into separate school-subject pieces. Project work helps pupils to relate their everyday life experiences to subject concepts. This paper also describes one example of project work concerning mathematics, science and consumer guidance.

About the concept "project work"

How may pupils be given learning experiences in mathematics which will connect real life situations to mathematical concepts in a meaningful way? School learning has been accused among other things of keeping context and action fully separate from and neutral to the learning content. The newest studies of learning, however, show that learning is strongly context-bound. Project work is one way to organize teaching, making connections to reality and life outside the school more central. Project work has been defined in many different ways. For example Leino (1989) has defined a project in the following way: "A project means developing ideas, carrying them out and evaluating the work done, and getting feedback, usually from a larger group or the teacher of the purposeful task." The following properties are mostly connected with project work: 1) activity, 2) problem-centredness, problem-solving, 3) responsibility for results, 4) goal-directedness, and 5) scientific working methods (Pehkonen 1992).

From the teacher's point of view, project work may be problematic, because the teacher may feel unable to manage the wholly-changed teaching situations and to adapt his new role as a guide, as a consultant and as a planner of learning situations (Blumenfeld et al. 1991). This requires changing usual classroom routines, because, in the classroom, several different actions occur at the same time during project work. Discussion and social interaction, which are an essential parts of project work, are a natural way in our culture to develop and form ideas, conceptions and beliefs. Therefore, pupils should be encouraged to discuss and to express their opinions, without a teacher asking and inhibiting them (Brown et al. 1989).

It has been stated that project work will lead to a better understanding of key principles and concepts, since pupils are put into a realistic and contextual problem-solving environment to investigate and to look for solutions. It demands a striving and active approach to the task for longer periods. It connects school subjects with each other and offers a broader view of the subject (Blumenfeld et al. 1991).

The orange juice project

The following school project was carried out in the sixth grade. It had its origin in the experiences pupils had received in learning geometry with different food packages. Pupils had measured them, spread them out and built new ones when investigating the capacity and the net of different solids. Another reason was the environmental week which was helt in our school. Pupils had figured out the amounts of rubbish, how to destroy it, they had become acquainted with composts and with recycling. The number and variety of packages aroused questions: Why, for example, do we have so many different juices, how are they different and how are these juices packed? The interest towards the environmental friendliness of the packages had arisen.

It was decided that each student should gather information about six different orange juices: the name of the product, the price, the amount of the content, the package material and the information about ingredients and nutrition. During one week, pupils also collected about fifty different bottles, cans and packages and brought them into the classroom. On the bulletin board we had a chart on which everyone wrote his or her information as soon as he/she had gathered it. At the end, we had information on one hundred and eleven orange juices.

After that the juices were categorized. We learned, that we had information about twenty-five different orange juices and also, how many cases of each we had in our data. We thought about, what this information meant. The class was now divided into working pairs or groups according to their own choice. Each group took some trademarks to investigate, and they received a computer data sheet with all gathered information. The group had to make a bar diagram, from which the frequencies of the juice trade marks could be read. The group also had to investigate the range of the prices for each juice and to calculate the price per litre for each. It was agreed that the work would be presented in the form of a poster so that at least all the above-mentioned information could be clearly read, and so that all the package types could be seen and possibly stuck onto the poster.

When the work was done after some days, we examined the bar diagrams. We reflected on what the height of the bar should tell us in this situation. The pupils gave the following suggestions: It may actually tell us how much different orange juices are consumed in the households of our students. It may tell the frequency of the juice trademarks in the shops or how the juice packages are demonstrated in the shops; or it may tell us about a special offer or about the appearance of the package or something else.

Then we examined the prices. In our data we had some trademarks with fixed price, but otherwise the prices ranged considerably. We discussed the reasons for that. Pupils explained this phenomenon by the fact that some shops are known to have high prices while others have low ones (for example sale markets), also special offers had their influence. As expected, the juices which required some water addition were the most expensive. Seldom did the information about the ingredients inform us as to how much fruit had been used in the preparation. So, we could only guess that perhaps the price and the quality were connected to. It also seemed that the price and the package had a connection. The juice packed in a glass bottle or jar was more expensive than the juice in a carton or a plastic package. A high quality-juice packed in a simple package was cheaper than the same juice (from the same producer) packed in a more colourful package. Also, the size of the package influenced the price. The smaller the package, the higher the price per litre.

We also examined the materials and the shapes of the packages, their recycling properties or how to destroy them. The most typical ones were waxed or plastic cartons, often insolated with aluminium folio. We also had plenty of glass and plastic bottles, but only one aluminium can. The glass bottles were the most friendly to our environment. One can easily recycle them. The plastic packaging and cartons are more problematic.

The cheapest, the healthiest and the most environmentally friendly way to use oranges is to eat them as such.

Conclusion

Project work is a good way to connect skills and the knowledge of different subjects. It is important for project work that there is a question or a matter to start with which can be formulated into problems. Advancing systematically to the structure of the subject is not meaningful and perhaps not even possible in projects. The origin of the project is in the world around us, not in the subject.

The mathematics needed in projects is usually quite simple. Abrantes (1992), when explaining the project experiments carried out in Portugal, states that the main mathematical aspects in projects come from statistics, graphs, propositions and scales, geometry and trigonometry. But, it is far more difficult to imagine the explicit use of functions or equations in project work. The mathematics we deal with in our everyday life situations is, after all, quite primitive.

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Primary teachers' conceptions on motivational concepts

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The author made a research study of methods that primary teachers used in motivating in mathematics. Some of the teachers were also interviewed and asked to explain how they understood the concepts "motivation", "motivating teaching" and "attitude/taking an attitude". The conceptions varied considerably from each other and also from the comprehension the author had.

When doing a research, the researcher usually expounds the results with regard to the theoretical background of the research. However, it is also essential to know how the subjects have understood the conceptions used in the research because concepts strongly affect the answers. The researcher and the subjects may have a totally different comprehension of the matters being researched and therefore it is even possible to draw wrong conclusions.

Background

In a research study (Pietilä 1993), the methods that primary teachers used in motivating pupils in mathematics, as well as what reasons caused differences between the teachers, were studied. The research was based on the constructivistic viewpoint of learning. According to this view, learning is an active internal process: an individual receives new information by relating it to his/her existing knowledge structure. If the information is hard to relate to, the individual changes his/her internal structure so that the structure becomes more suitable for receiving the information (Davis et al. 1990). The sensibleness of learning is also important because without an application the knowledge is useless to the pupil (Leino 1993).

Pintrich's (1988) model of motivation was chosen as the basis of the theoretical background because it fullfilled both the requirements of a constructivistic viewpoint and sensibleness. According to the Pintrich's model, motivation depends mostly on student's expectancies, task value and goal orientation. Expectancies include perceived competence, test anxiety, perceptions of task difficulty, student's beliefs about efficacy, control and outcome, and expectation of success. Task value includes attainment value, interest value and utility value, and goals can be either long term or short term goals.

The author's comprehension of motivation and related concepts was as stated above. In order to find out what the conceptions of subjects were like, a small interview was performed before the questioning. Eight teachers were asked to explain their conceptions of the most essential concepts of the research: "motivation", "motivating teaching" and "attitude/taking an attitude". Their answers are presented below.

Motivation

First, the subjects were asked to explain specifically how they understood the term "motivation". In all the answers, the teacher's role as the motivator was strongly stressed out. One half of the teachers considered motivation as an instantaneous means to get the pupils' attention on the subject being taught. They gave reasons for their view by saying: "It is like a bait through which the subject is entered." "It is getting the pupils' attention, it can be done in many ways, for example, with a song or a picture. It depends on the situation." That is, they considered motivation as a short term process connected only to one school hour at a time.

The other half defined motivation as a continuous long term process that could not be separated from normal teaching. They demonstrated their view by comments like "It (motivation) must be connected to the subject in order not to be drawn away from the reality." "It is part of the work and the methods, it is a part of a big entity." "The pupils understand the reason for learning; learning is not just an obligation." "The pupils have high self confidence, they believe they will manage."

Motivating Teaching

To find out the teachers' conception of the term "motivating teaching", they were asked to tell what kind of teaching they found to be motivating.

Six of those interviewed found it important that the pupils receive information about the utility and the application possibilites of the subject under discussion. Another prevailing idea was that motivating teaching makes the pupils interested and inspires them: "The teacher gets the attention of the pupils on the subject in any way possible."

The importance of the enthusiasm of the teacher was pointed out by two teachers: "Motivating teaching depends on the personality of the teacher, the teacher him/herself must be interested. The pupils notice if you behave superficially and just hand out assignments. Only a good student gets excited then ."

The 1st or 2nd grade teachers emphasized the importance of learning in motivating teaching: "Having fun does not necessarily mean only playing." They did not stress the meaning of utility.

Attitude and taking an attitude

Five teachers considered attitude as an advanced comprehension that affects on our behavior and our stand on various things. Their comments were: "It is how you yourself stand in relation to things. If you take a positive stand toward something you behave positively and like it, but if you take a negative stand you probably do not like it." "If you want to do and learn something you have to have a positive attitude."

Four teachers believed that the attitudes are passed on from generation to generation: "Parents tell their children that they have never understood mathematics, so it is not a wonder if he or she does not understand mathematics either. That is how the wrong kind of attitude is formed in children."

In three teachers' opinions an attitude can be improved by motivating: "An attitude can be improved by spurring on; poor pupils' level of requirements must not immediately be lifted too high." According to one teacher's experience pupils' attitudes change.

Conclusions

Teachers had quite a number of various conceptions about the concepts been asked. Motivation was understood to be either a short term process, connected only to the matter been taught, or a long term process that could not be separated from normal teaching. Teaching was thought to be motivating when the pupils were told about the utility and the application possibilities of the subject under discussion. The importance of the enthusiasm of the teacher and the importance of learning were stressed in defining motivating teaching. Attitude was considered to be an advanced comprehension that affects our behaviour. Some believed that attitudes are passed on from one generation to another and some that attitudes can be improved by motivating.

Noticeable variations in the conceptions of the subjects showed that people comprehend differently things that are often considered well-defined by researchers. Clarifying the conceptions of the subjects and taking them into consideration in interpreting the results seems to have been essential in getting unbiased, reliable results.

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New components for the study and evaluation of mathematics

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All the lessons in our comprehensive school have been divided into six-week periods. In every grade of the secondary school there are three periods of mathematics during a school year. Mathematics is studied 6 lessons a week for six weeks (a total of 36 lessons). The lessons have been double lessons (2x45 min). The division of the lessons into periods has created a situation in which changes in mathematics teaching have been natural but also a necessity. The aim of this article is to give an outline of the components used in the assessment of mathematics studies.

Future Changes

In the new outline of the comprehensive school curriculum the pupil is seen in an active role acquiring, processing and recording information. In the teaching situations he learns new concepts by study, experiment and concrete examples. The focus will be changed from teaching to a balance between learning, teaching and evaluation.

The study of mathematics will include new and more versatile components.The ability of the pupil to classify, analyze and model new situations cannot be evaluated merely with a traditional written exam. We need new components for the assessment of mathematics studies.

Functions of Evaluation

In the active learning, the learning process and the total performance of the pupil get more emphasis. One task of assessment is also to give useful information to the learner and help him to develop his own performance. As the pupil is now regarded as an active learner who takes the responsibility for his own learning, he has to be regarded in an active role, evaluating how he has learned and, eventually, evaluating the teaching he has received, too.

The purpose of assessment, in addition to giving the teacher information on learning and his own work, is also to encourage and positively direct the learner.

Self-Evaluation

The pupil sets himself goals in the entity studied, and later evaluates how he has reached these goals. Experience has shown that the goals the pupils set themselves are on very different levels, but very realistic. On the other hand, we believe that the pupil learns to take responsibility for his studies this way. Here is an example of how three pupils set their goals and how they reached them. The subject was the concept of power.

My goals and expectations	**My strongest points**	**My estimate of how the goals were achieved**	**The period positive: negative:**
to get a better grade, to behave properly	*I'm good with numbers*	*I've behaved well I've worked on many problems*	*I don't know*
I want to learn as much as possible about power	*I'm rather active because I'm interested in maths*	*I've reached my goals well, the exam went well, and the project work, too*	*interesting way and they were even interesting. I'm no usually interested in planets*
to get at least the same grade, to earn about power	*I understand easily*	*I think I have studied rather well*	*the exercises were versatile, we could have studied about power a bit quicker*

A pupil may evaluate his own work and learning by discussing with his teacher. The following is an example of a conversation taken from a videotape. The pupils have a portfolio in which they collect their work. "Ville, which of your assignments has been the most interesting?" Ville:" *The project work on the number of the diagonals in a polygon.*" "Why?" Ville:"*Well these diagonals are a new thing, how they increase when the polygon grows.*" "Which was more interesting in the work, geometric drawing or the final result?" Ville:" *The final result, the formula for calculating the diagonals.*" The pupils were also asked which task had been the most difficult, easiest etc.

A pupil may also evaluate his learning in many other ways. At the end of the study period, when there are a few minutes left, the pupils may be asked to write down concisely what they have learned. When a pupil evaluates his own work, the teacher always gets valuable information.

More components in the assessment process

Evaluation of the pupils' research papers and project work will be part of the assessment process in the teaching of mathematics. The division of the mathematics lessons into periods has made it possible to carry out more comprehensive entities and work. The pupils have collected their work in secondary school in a portfolio (evaluation folder), where they have the project and research papers, essays, exams, tests and old notebooks. The work done in one year provides the teacher with a broader view of each pupil and his contribution to his studies.

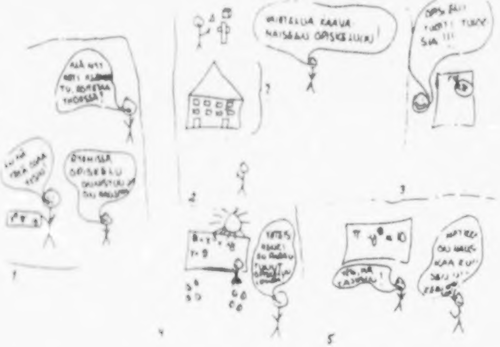
The teacher has evaluated part of the project papers in the portfolio by using the evaluation forms he has developed. When the pupils do project work for the first time, it is worthwhile to show them what parts are included in a written presentation. This makes it easier for the pupils to evaluate their own work and other pupils' performance in the future.

The teacher does not always have to do the assessment. Another group may evaluate a groupwork. Also, the group itself may evaluate the efficiency of the group and the success in reaching the goals. We have also experimented with situations where a pupil assesses another pupils performance.

The evaluation form may be planned so that it teaches the person doing the evaluation. Here is an example. The task of every pupil was to plan a map and separate the written instructions of the route he had planned, in the vicinity of the school, so that the end point was not expressed.Another pupil checked how well he followed the instructions and walked through the route with the map. After this, he evaluated the usefulness of the map. He also evaluated the number of different instructions based on mathematics, that the pupil drawing the map had used in his instructions. After the work was completed,the teacher had information on the knowledge of both the maker of the map and the pupil checking it.

The teacher assesses his work

Quite a few of the evaluation methods presented above give the teacher feedback on his own work. Professor Gilah Leder, from Australia, has said that one way to evaluate one's teaching is to ask the pupils to draw a picture of a mathematics lesson. The pupils who get teacher-centered teaching often draw the blackboard and the teacher. The pictures rarely indicate communication between pupils. As an example, here is one picture of a mathematics lesson, drawn by a pupil whose teaching had been developed towards active learning.



1. Don't get upset, lets try together! I can't do it alone! Learning in groups is successful and fun! 2. A change from the routine. 3. Studying produced good results. 4. The atmosphere has improved during my studies. 5. Yes, I got it. Maths is fun when you get to use your brain.

To conclude

Evaluation, which includes several different components, supports development in the teaching of mathematics, correspondingly, with the diversification of mathematics teaching the expectations concerning the diversification of evaluation also become greater.

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